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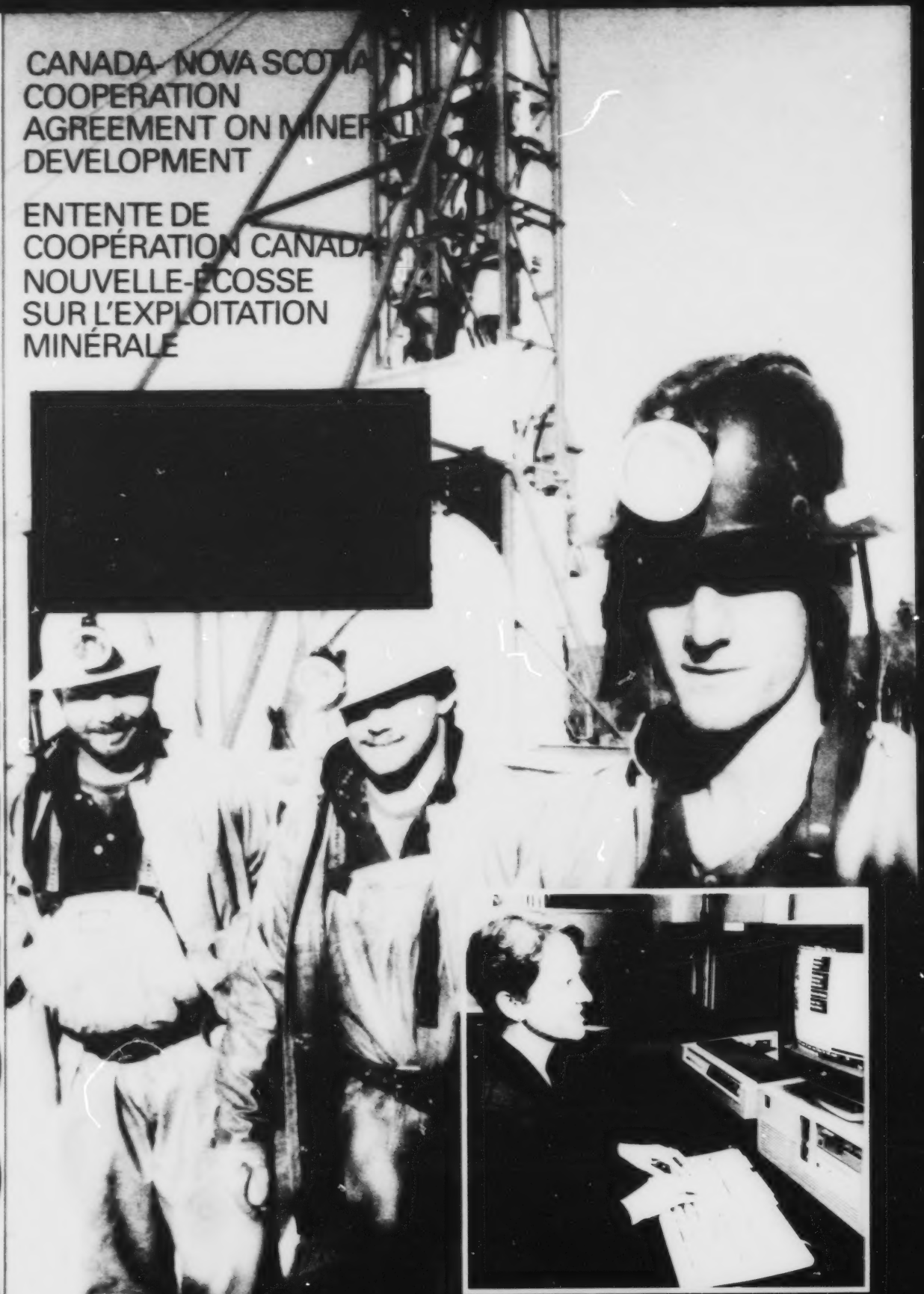

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VOL. V of VII

A STUDY ON THE CONTR[illegible]
OF GROUNDWATER HAZAR[illegible]
AT GAYS RIVER MINE

VOLUME V

HYDROCHEMISTRY ASSESSMENT OF MINE WATER GAYS RIVER LEAD-ZINC MINE

by: Jacques Whitford Environmental Ltd.

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WESTMINER CANADA LIMITED
SEABRIGHT OPERATIONS
HYDROCHEMISTRY ASSESSMENT
OF MINE WATER
GAYS RIVER LEAD-ZINC MINE
MILFORD STATION, HANTS COUNTY, NS
PROJECT NO. 7170

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PROJECT NO. 7170

FINAL REPORT TO

WESTMINER CANADA LIMITED

SEABRIGHT OPERATIONS

HYDROCHEMISTRY ASSESSMENT OF MINE WATER
GAYS RIVER LEAD-ZINC MINE
MILFORD STATION, HANTS COUNTY, NS

Jacques Whitford Environment Limited
February 10, 1992

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1.0 INTRODUCTION

1.1 General

Jacques Whitford Environment Limited (JWEL) at the request of Westminer Canada Limited (Westminer), has conducted a hydrochemical investigation and assessment of the Gays River Mine, located 70 km east of Halifax, Nova Scotia. The work program was carried out in accordance with JWEL Proposal W-7170, dated May 22, 1991.

1.2 Previous Investigations

The Gays River Mine has experienced significant inflows of groundwater over the past decade, to the extent that mine operations were often disrupted. Numerous investigations, were conducted between 1974 and 1990, most of which involved geotechnical, mining and hydrogeological investigations.

A series of monitoring wells (H-series, OW-series and DW-series) were drilled by Dames & Moore in the late 1970's and 1980'S. Exploration test wells (ETW) 1, 2, 3 and 4 were drilled by Leggette Brashears & Graham Jan. - Feb., 1982. Many of these wells are now used to monitor groundwater levels. A program of shallow monitor well drilling (P-series wells, Drawing 7170-1) was carried out in the vicinity of the tailings basin by Porter Dillon in 1989 for environmental monitoring purposes. Table 1 summarizes available data for all monitor wells at Gays River.

A geochemical assessment of the Westminer data to December 1990 was performed by Meyer (1991), who conducted a detailed evaluation of historical borehole data, and mine water discharge up to Dec., 1990. This data is correlated with mine pumping records, rainfall data, and mine dewatering progress. Meyer concluded that a significant degree of surface water inflow was mixing with the mine water, varying seasonally with rainfall, river stage and flooding events. Meyer concluded that the mine discharge rate was at equilibrium at about

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TABLE 1 SUMMARY OF GROUNDWATER MONITORING WELL CONSTRUCTION AT WESTMINER GAYS RIVER MINE

HOLE #	STATUS	DEPTH (m)	DATE DRILLED	DIAMETER (mm)	REF	NORTHING	EASTING	COLLAR RL	SWL May 15/91	SWL	DATE*	LOCATION
DW-1	OBS	109.7	04/01/80	254	2	7246	8693	518.47	40.02			NW of 104/107
DW-2	OBS	139.6	14/01/80	305	2	7294	8891	525.29	24.71			E of 104/107
DW-3	OBS	125.0	01/80	406	2	6887	8540	530.52	70.74	23.87	15/03/80	
ETW-1	OBS	119.8		155	3	6850	8485	535.22	73.82			S of 118 ore
ETW-2	OBS	112.2		254	3	6745	8175	542.81	82.42			W of 301 drift
ETW-3	OBS	91.4		200 (to 58m)	3	6610	7920	546.67	69.95			501 orebody
ETW-4	OBS	88.4		200	3	7610	9425	521.3	38.16			Taylors Pond
H1	ABAN	73	22/07/74	155	1					9.14	27/09/74	
H2	ABAN	36.6	28/08/74	114	1					5.00	27/09/74	
H3	OBS	106.7	27/07/74	155	1	6251	7667	555.84		43.53	15/03/80	
H4	OBS	96.9	22/08/74	155	1	6718	8043	550.05	91.76d	41.66	15/03/80	W of 301 ore
H5	OBS	18.9	23/08/74	155	1	7370	9291	515.27	8.75	12.53	15/03/80	NE of 201
H6	ABAN	76.2	05/09/74	155	1					5.20	27/09/74	
H7	OBS	54.3	26/09/74	155	1	7469	9344	519.35	43.47d	40.32	15/03/80	
OW-1	ABAN	45.7	15/01/80	155	2	7214	8494	520.29		10.23	15/03/80	
OW-1A	OBS	103.6	15/02/80	155	2	7181	8473	518.21	42.50	13.36	15/03/80	E of 119 ore
OW-2	OBS	86.3	04/02/80	155	2	7270	8840	522.36	21.40	40.23	15/03/80	E of 104/107
OW-3	OBS	52.4	02/80	155	2	7358	9071	519.44	28.64	27.90	15/03/80	N of 201
OW-6	OBS	31.1	02/80	155	2	6704	8337	544.98	23.17	20.10	15/03/80	
OW-7A	ABAN	90.5	02/80	155	2							
P1	OBS	21	1989	25+38	4	5142.5	9118.8	524.63		5.90		
P2	OBS	18.6	1989	25+38	4	4805.1	8544.5	525.1		4.25		
P3	OBS	4.2		19	4	4957.2	8083.9	520.5		0.90		
P4	OBS	7.5	1989	25+38	4	6177.1	8698.9	533.21		5.71		
P5	OBS	18	1989	25+38	4	6656.2	8773.9	532.16				
P6	OBS	12.1	1989	50	4	7355.4	8614.9	515.79		4.36		

REFERENCES

* – Pumping test on DW-3, March 15, 1980

1. Dames & Moore (1974) Reconnaissance Hydrology Imperial Oil/Cuvier Mines, Gays River Mine, N.S.
2. Dames & Moore (1980) 1979-80 Groundwater Program; River Diversion and Flow Regulation Feasibility Investigations, Gays River Mine, N.S.
3. Leggette, Brashears, Graham (1982) Phase I Hydrogeologic Investigation Gays River Mine.
4. Porter Dillon Limited (1989)

Table 1 (cont'd)

HOLE #	AQUIFER	TOP (m)	BASE (m)	EST. FLOW (USgpm)	WATER BEARING ZONE		FROM (m)	TO (m)	SCREEN SLOT	SCREEN DIAMETER (mm)
DW-1	TRENCH FILL (lst, breccia)			10	FULL DEPTH		85	100	#40	200
DW-2	GYPSUM-CAV	76	82		WELL NOT COMPLETED					
DW-3	GYPSUM-CAV	83	84	2500	Inside 10" screen		82	88	#40	200
ETW-1	GYPSUM-CAV	85	115.8		OPEN HOLE (150mm BELOW 50m, cavity @ 106m)					150
ETW-2	GYPSUM-CAV	64	79.3	40	OPEN HOLE (150mm BELOW 70m, cavity @ 106m)					200 screen damaged
ETW-3	TRENCH FILL			400	OPEN HOLE (150mm BELOW 96m)					
ETW-4	GYPSUM ?				OPEN HOLE (150mm BELOW 82.3m)					
H1	CARBONATE (destroyed)			40	15.2	30.5	24.4	30.5	PVC	51
H2	CARBONATE	30	41		27.4	40	31.1	41.2	PVC	51
H3	GYPSUM-CAV	50	60	175	WELL SANDED TO 67m					
H4	SAND	49	56	5						
H5	TILL	6.7	19		none		13.7	18.9	OPEN HOLE (150mm BELOW 14.6m)	
H6	SAND	5.5	10	100	grouted to surface				caved at 14.6m	
H7	SAND	5	42	70						
OW-1	GYP/SAND	39.6	45.7	150	hole abandoned at 45.7m due to lost circulation, cavity at 45m					
OW-1A	GYP/CARB	96	102		52	103.6	96	103.6	#40	200
OW-2	TRENCH FILL	71	77	35	NONE		70	76	#40	155
OW-3	GYPSUM	44	47		26	52.4	44.2	47.2	#40	155
OW-6	TRENCH FILL	26	30		18.9	31.1	26.5	29.6	#40	155
OW-7A	GYP/CARB	75.3	90	30	42.7	90.5	92.9	90	#40	200
P1	TILL									
P2	TILL									
P3	TILL									
P3	TILL									
P4	TILL									
P5	TILL									
P6	TILL									

Modified from Meyer, 1991

15 cubic meters per minute (4000 USgpm), fluctuating about 2 to 4 cubic meters per minute due to seasonal or flooding events. Increased discharge through additional drainholes would be required to achieve the desired level of drawdown. The primary source of the mine water was believed to be a combination of formation water from the karst gypsum aquifer and surface water during flooding of the river floodplain. Recommendations were made for (1) additional drainholes in the 832, 807, 803, and 804 areas; (2) monitoring of suspended solids at 118 sump area, (3) install vertical deep dewatering wells, and (4) conduct a thorough hydrogeological investigation of the shallow sand aquifers. Recommendations 1, 2, and 4 were implemented by Westminer in 1991, concurrent with this hydrochemistry assessment.

A panel of experts was jointly convened by Westminer and CANMET at Gays River on May 13 and 14 of 1991 to discuss possible options for resolution of the mine water problem. The panel concluded the most likely source of the water was the karstic gypsum bedrock aquifer immediately adjacent to the trench deposits. This hydrostratigraphic unit is recharged on a regional basis by ambient rainfall, and locally by sinkholes located on the river flood plain, on the river bottom and hidden beneath major permeable sand and gravel deposits in hydraulic connection to the river. Priority work was to focus on dewatering areas of the mine from a series of underground horizontal boreholes drilled through the carbonate into trench and gypsum cavities, and locating surface water recharge pathways into the mined area.

One suggestion presented by the panel was to conduct a thorough assessment of available water quality compliance monitoring data, and to conduct a baseline survey of the spatial variation in chemical quality and isotopic nature of various waters throughout the mine complex. This information would aid in interpretation of the mine hydrogeology, possible mine water sources, and possible mine water recharge pathways. Trends generated from the chemical data could be used in conjunction with the physical investigations to interpret the source and fate of mine water transport.

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1.3 Objectives and Scope

The objectives of this work are:

1. Review existing water quality data compiled by Westminer from various mine water quality monitoring sources and identify any trends or parameters useful in interpreting mine water sources.

2. Design and implement a baseline water quality monitoring program and sample collection protocol sufficient to provide a reasonable coverage of major mine water inflows and possible sources.

3. Interpret the spatial baseline water chemistry analysis results in light of the current mine water problem to identify possible mine water sources and infiltration pathways.

4. Recommend a long term mine water monitoring protocol for the Gays River Mine compatible with proposed mine water modelling and hydrogeological investigations.

5. Provide comment on the adequacy of the existing monitoring strategy, and recommend modifications if applicable.

This study deals specifically with the review and assessment of baseline monitoring data provided by Westminer, and the interpretation of hydrochemical data collected in June 1991. The temporal variability of the mine flows is addressed through review of mine discharge and tailings pond chemistry monitoring data collected over the past two years. The spatial variability of mine water chemistry is addressed through the 1991 field sampling program results. Emphasis is placed on the new data collected in 1991.

It is anticipated that this information will be integrated by Westminer with the results of other investigations currently on-going at Gays River to resolve the mine water problem.

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1.4 Report Format

This report is presented in five sections. Section 2 is an assessment of the temporal variability of the mine water chemistry through a review and interpretation of the approximately two years of monitoring data provided by Westminer. Section 3 is an assessment of the spatial variability of mine waters through interpretation of the results of field monitoring, underground sampling sites, surface water sampling sites, deep monitor well sampling, isotope analysis and hydrochemical profiling of sinkholes. A summary of Key Conclusions is presented in Section 4, and Recommendations for further work and a mine water monitoring strategy are presented in Section 5.

1.5 Hydrogeological Setting

The Gays River lead-zinc mine is located in the central portion of Nova Scotia near the village of Milford, approximately 70 km by road from the city of Halifax, N.S. (Figure 1).

The mine site is situated at the confluence of the Main and South Branches of Gays River, which drains to the Shubenacadie River, ultimately draining to the Bay of Fundy, 50 km to the northwest. The flow rate of Gays River ranges from 5.7 to 1022 cubic metres per minute (1500 to 270,000 USgpm), with flood plain inundation at flows exceeding 719 cubic metres per minute (190,000 USgpm) (Meyer, 1991). The area is forested, rolling karstic terrain with an average elevation of 15 m above sea level in the vicinity of the mine.

Average annual rainfall in this area is estimated to be in the order of 1255 mm, with an average recharge potential of 12 to 17% based on hydrogeological studies throughout the province. Recharge to the bedrock aquifers supplying the mine complex is expected to be through regional recharge of the karstic gypsum bedrock, and locally from the Gays River, likely through sinkhole and sand channel deposits in hydraulic connection with the river bottom and bedrock and trench units.

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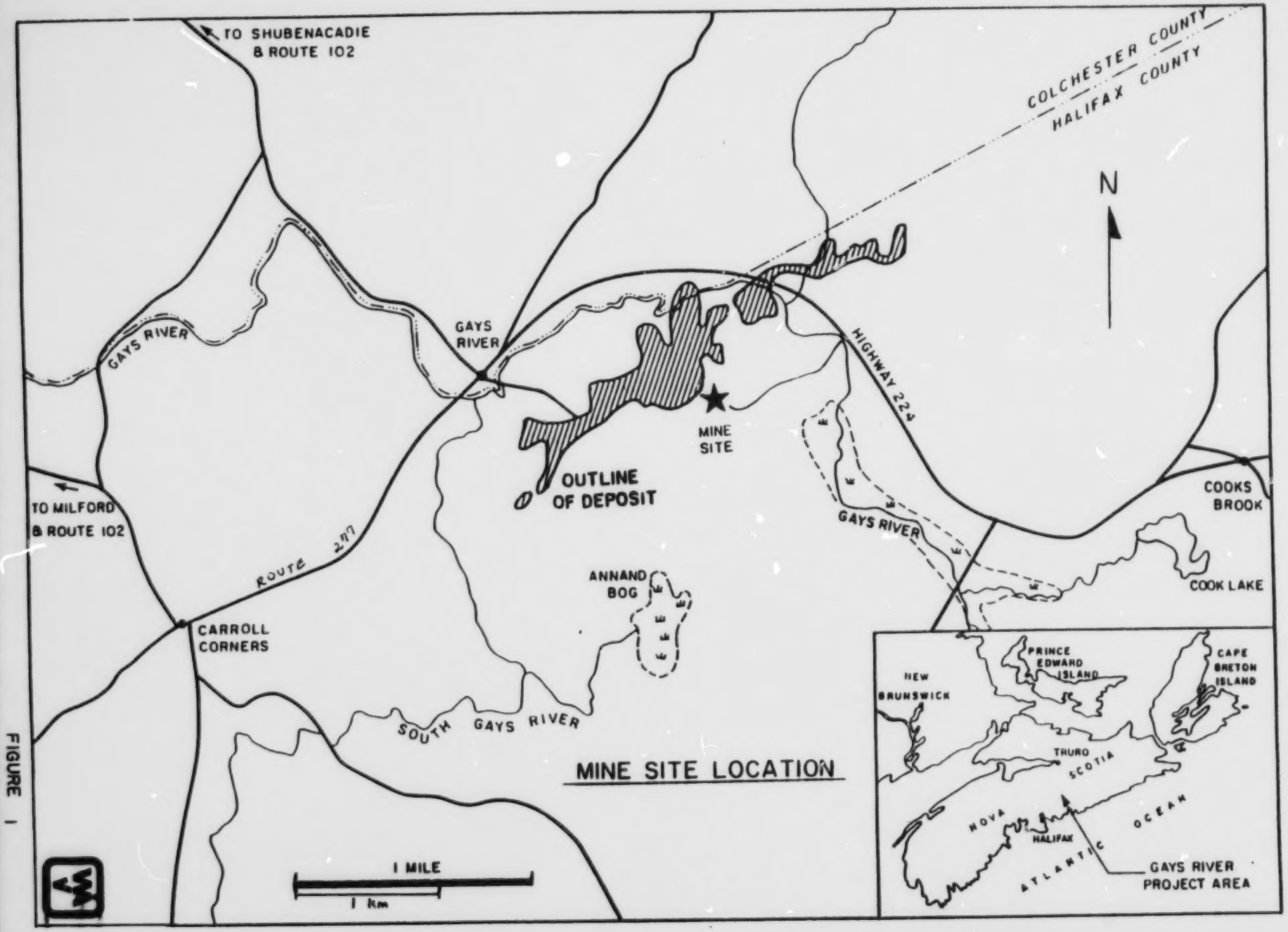
TO SHUBENACADIE & ROUTE 102
COLCHESTER COUNTY
HALIFAX COUNTY
N
GAYS RIVER
GAYS RIVER
HIGHWAY 224
MINE SITE
OUTLINE OF DEPOSIT
TO MILFORD & ROUTE 102
ROUTE 217
GAYS RIVER
COOKS BROOK
COOK LAKE
ANNAND BOG
CARROLL CORNERS
SOUTH GAYS RIVER
MINE SITE LOCATION
1 MILE
1 km
NEW BRUNSWICK
PRINCE EDWARD ISLAND
CAPE BRETON ISLAND
TRURO
SCOTIA
NOVA
HALIFAX
ATLANTIC
OCEAN
GAYS RIVER PROJECT AREA

FIGURE 1

The equilibrium recharge to the mine appears to be in the order of 15 m3/min (4000 USgpm). Assuming a 155 km2 river catchment area, this rate is about 30% of average annual recharge potential assuming 12% recharge. This flow rate decreases in winter when recharge is limited by freezing, and increases during heavy rainfall events in spring and fall when the river flood plain is inundated (Meyer, 1991). Based on monitor well observations during recharge events, the primary direction of recharge is from the north and east, in the vicinity of Gays River and an area of extensive sinkhole development, including Taylor's Pond (Meyer, 1991).

Detailed descriptions of mine geology and hydrogeology are presented in McKee & Hannon (1982, JWA 1990, and Meyer, 1991). The area is overlain by moderately thick low permeability glacial till, with extensive areas of permeable sand and gravel deposits in the vicinity of the mine site. Two large drumlin structures and a commercial sand and gravel operation dominate the surficial geology of the site.

The mine is developed in a carbonate-hosted lead-zinc deposit situated along the contact between the crystalline basement rocks of the Ordovician aged Meguma Group and the Mississippian aged Windsor Group comprised of gypsum and limestone. Five hydrostratigraphic units and potential mine water recharge pathways were identified for the Gays River Mine systems (Figure 2):

Goldenville Quartzite (E2) - a thickly bedded, highly jointed subgreywacke, with minor slate, generally impervious to dry, with occasional fracture zones. Typical domestic well yields are in the order of 0.5 to 5 igpm with rare flows of 50 to 100 igpm range reported in fault or shear zones.

Basal Breccia - a basal unit of quartzite blocks in a carbonate complex in a pebble conglomerate between the basement and carbonate reef structure. This unit is typically dry except where fractured or in contact with the carbonate-trench contact (not shown).

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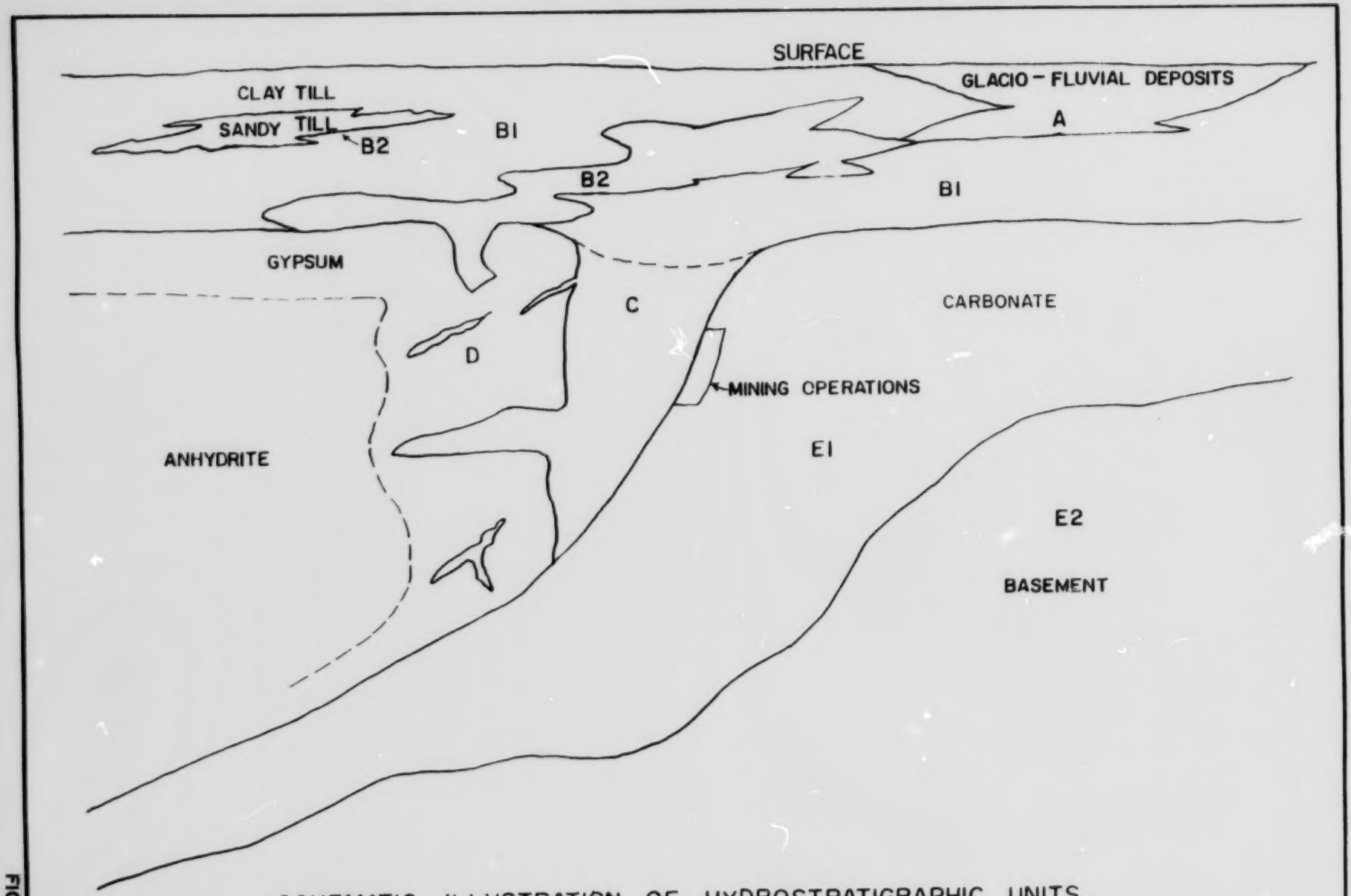

SCHEMATIC ILLUSTRATION OF HYDROSTRATIGRAPHIC UNITS

FIGURE 2

Carbonate (E1) - generally massive limestone, impervious and dry. The limestone is dolomitized and mineralized on the northwest side of the reef. The contact with the trench materials is de-dolomitized by calcium-rich groundwater, to a vuggy, black limestone, which may be permeable and saturated.

Evaporites (D) - gypsum along the trench contact and anhydrite, west of trench area. Numerous caverns and solution cavities were identified during the exploration drilling. Many cavities are filled with gravels, calcareous mud and silts. These cavities are likely recharged regionally and locally from overlying sinkhole development. Pumping tests conducted on DW-3 indicated an aquifer transmissivity in the order of 340 to 800 m2/day, with greatest permeability in an east-west direction along the trench-gypsum contact (Meyer, 1991).

Cretaceous Trench deposits (C) - mud, sand and gypsum deposited in an erosional trench formed between the carbonate reef and gypsum during lower Cretaceous period. The trench -bedrock contact is a steeply dipping erosional feature between the gypsum and carbonate. Although most of the materials are expected to be of low hydraulic conductivity, several horizons of permeable sand and gravel have been encountered (JWA 1991, in prep), and significant flows (up to 100 L/s with suspended solids of 4 to 5 tonnes per hour at 119G) have occurred along soil pipes, gravel lens a few cm to 25 cm in diameter and fluvial channels along the contacts with the gypsum and the carbonate units. Material typically described as 10 to 20 % gravel & boulders, 40 to 50% sand, 20% silt and 20% clay fraction.

Pleistocene Deposits - Thick deposits of low mantle permeability glacial till (B1), with interspersed layers of wet sand till (B2) overlying both the Cretaceous trench materials and the evaporites. This is locally incised and infilled with fluvial deposits comprised of permeable, saturated, coarse sand and gravel, primarily in the portal area, and 118-119 mining areas (A). Leakage from the glacio-fluvial deposits (A) through coarser units of the till (B2) to the underlying trench or evaporite aquifers in hydraulic connection to the mined area is a hypothetical source of mine water.

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Recent - relatively impermeable river alluvium along Gays River is believed to prevent large scale recharge of the river into the mine workings. However, several possibly active sinkholes are identified in the river channel and river floodplain. An investigation of the permeable deposits currently underway (Golder Assoc. Limited, in progress) has identified permeable sand deposits in hydraulic connection with Gays River.

The above possible water sources are addressed in light of the chemistry of mine waters observed throughout the mine.

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2.0 REVIEW OF TEMPORAL MONITORING DATA

2.1 Methodology

A project inception meeting was held with Westminer representatives on May 28,1991 to finalize the scope of the work, collect available information compiled by Westminer, and to inspect prospective underground and surface source water quality sampling locations.

Copies of groundwater level monitoring data, water quality monitoring data and other monitoring data were collected from Westminer, who maintain this information on a Lotus format database. Available resource and monitoring data relevant to this hydrochemical assessment includes:

1. Mine water effluent quality monitored on a weekly basis at the mine water discharge weir (April 1989 to Present; Westminer file GRH2OSM5.WK1).

2. Daily groundwater elevation monitoring data for selected deep monitoring wells, including mine water discharge rates, and daily precipitation data from Halifax International Airport (April 1989 to Present; Westminer Files GRGWM9TL.WK1 (1989), GRGWMTL1.WK1 (1990), GRGWMTL3.WK1 (1990) and GRGWM91.WK1 (1991).

3. Weekly water quality data from compliance monitoring point WCI-GR1 at tailings pond outfall (April 1989 to Present; Westminer File No. GRMILHO5.WK1 and GRMILHO3.WK1 (1989), WCIH2O2.WK1 (1990),WCIH2O3.WK1 (1991)).

4. Weekly water quality monitoring data for compliance station "A" which includes mine site runoff only. (Westminer file PTA2H2O.WK1).

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5. Suspended solids monitoring at drain holes in the 118 sump drain holes, (Feb to May, 1991, file TSS118.WK1).

In addition to the above information which pertains to the mine dewatering operation initiated by Westminer since April 1989, there exists several previous studies and reports which contain some hydrochemical data pertinent to this assessment. However, most of this information is related to samples from individual boreholes collected at the time of drilling (1974 to 1984), Gays River water chemistry, and some effluent monitoring chemistry. Given the intermittent nature and the quality of the older data, it was decided to focus the hydrochemical assessment based on the Westminer databases, which provide an excellent degree of continuity over a period of two full years, including an anomalous wet fall in 1990, and a record dry summer period in 1991. Reference to older data is made where applicable.

2.2 Background Hydrogeochemistry

The existing water quality database gathered by Westminer since 1989 was reviewed by the hydrogeochemist to identify any water quality trends which would indicate possible mine water sources or pathways, and data deficiencies.

The data includes major ion and trace element data for mine waters and compliance monitoring points, turbidity, suspended solids, mine water levels, river levels, precipitation data and other types of data which are not dealt with here. The geochemical data was gathered mainly for compliance monitoring purposes, but it has proven useful in determining sources contributing to mine waters. It has aided in interpreting the spatial geochemical data gathered during this study. In addition to this, the changes in bulk mine water chemistry over time can indicate changes in the component of water from various sources.

The following sections deal with geochemical data gathered at the mine discharge weir and at the Tailings Pond discharge point. Major ion data are dealt with first with emphasis on

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the Mine Discharge water, as these data are incomplete for the Tailings Pond Discharge. The second section deals with trace element data.

2.2.1 Major Ion Data

The major ions Ca^{2+}, Mg^{2+}, Na^{+},K^{+}, SO_4^{2-}, HCO_3^{-} and Cl^{-} were analyzed in the mine waters over the two year period; however the cation record is incomplete for the tailing pond discharge, with only sulfate continuously available for the period of record. Hydrogen ions are not normally considered part of the major constituents but pH is included here because of its importance in the geochemical environment.

Piper diagrams by Meyer (1991) and in Figures 8a to 8c, (this report) show the mine waters and surface waters to be wholly dominated by $CaSO_4$ as a result of gypsum in the bedrock and overburden. River waters tend to have higher components of both NaCl and $CaHCO_3$ than mine waters, but also exhibit a CaSO4 signature as a result of baseflow from gypsum aquifers and gypsum rich tills in the watershed. Total ion concentrations in river water tend to decrease during the wet periods, and increase during dry periods. However, river water ion concentrations can be almost as high as mine waters if measured during low water periods downstream of the tailing pond discharge, as was the case in this study. Chemical analyses of tailings discharge waters show results which are similar in major ion composition to those in mine discharge waters.

Because of their high relative concentrations, Ca^{2+} and SO_4^{2-} tend to have an overpowering effect when examining changes in composition of the mine waters. One way of overcoming this problem is to plot the saturation indices of various species. The saturation indices of gypsum and calcite are plotted against each other at the top of Figure 3. A saturation index of greater than one indicates supersaturation with respect to these parameters. The saturation index of gypsum is controlled by Ca^{2+} and SO_4^{2-} only, while that of calcite is controlled by Ca^{2+}, HCO_3^{-} and pH. The

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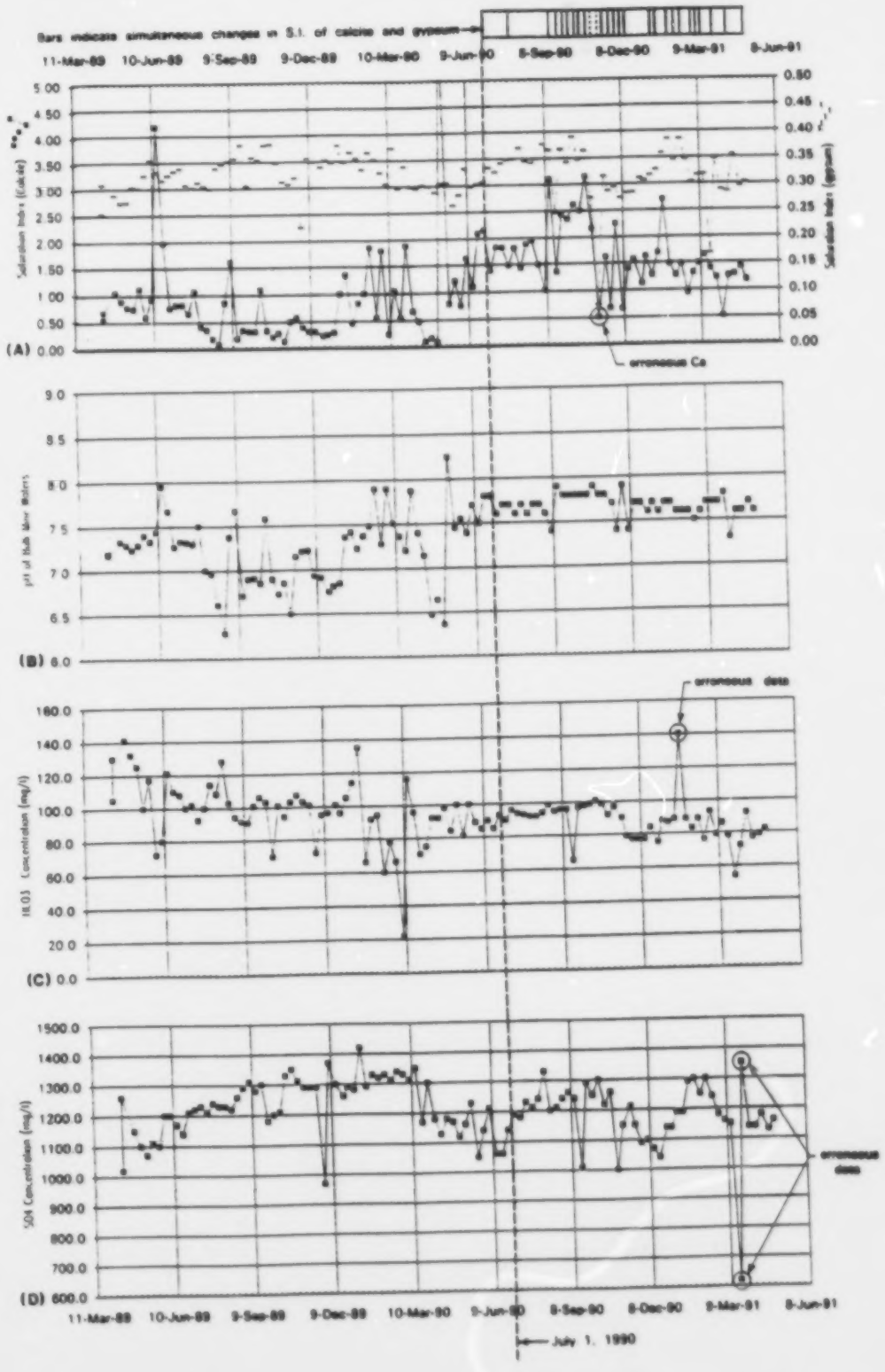

BULK MINE WATER DISCHARGE SHOWING THE TEMPORAL VARIATION IN CALCITE AND GYPSUM SATURATION INDICES, pH, AND CONCENTRATIONS OF SULFATE AND ALKALINITY

FIGURE 3

saturation index of gypsum shown in Figure 3 varies between 0.25 and 0.40 which indicates that gypsum is still actively being dissolved as these waters travel through the Windsor Group. The saturation index of calcite varies between 0.5 and 3 but is generally above 1 (for reasons discussed below, only values after July 1, 1990 can be considered valid). This suggests that for most of the time, calcite is actively being precipitated in the bulk mine waters and possibly also in waters from individual points in the mine. Supersaturation with respect to calcite almost always occurs when gypsum waters meet carbonate waters and therefore these conditions suggest that some degree of mixing is taking place between groundwater of the Carbonate aquifer and Gypsum aquifers.

Saturation indices can also aid in interpretation of the dominant fluctuations in bulk mine water chemistry. The mine water chemical load can be considered to be a result of mixing from three sources: the carbonate/reef aquifer; gypsum of the Windsor Group; and surface waters (including shallow sand and gravel aquifers above the mine). Surface waters, whether rain or river water, have much lower total dissolved solids than bulk mine waters. The shallow aquifer waters overlying the site are derived from river water and rain water infiltration. Influxes of surface waters will dilute mine waters as a whole and the saturation indices of both gypsum and calcite will tend to fall. Any reduction in the surface water component in the bulk mine waters will cause the opposite effect and both will tend to rise. An increase or decrease in the component of waters from the gypsum is probably, in effect, the same as a decrease or increase in the component of surface waters. An increase in saturation index of calcite with a corresponding decrease of that of gypsum may be a result of an increase in the component of waters from the carbonate.

The effects on saturation index mentioned above, could be caused by other geochemical conditions. Changes in other variables such as pH will result in changes in saturation index. The pH exhibits only a small variation in the 1991 spatial data (Table 7), but shows a more pronounced seasonal variation in the temporal mine

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discharge data (Table 2) and tailings pond data (Table 3). Figure 3 shows that, after July 1, 1990, the saturation indices of calcite and gypsum tend to vary together most of the time. Periods of simultaneous fluctuation of the saturation indices of both calcite and gypsum correlate well with high rainfall and high river conditions over this period. This suggests that the dominant changes in mine water chemistry result from volumetric changes in amount of surface water or shallow aquifer water as a component of the bulk mine waters. Based on these results, good hydraulic connection between surface and the mine is likely, at least in the last year.

Unfortunately, the pH and bicarbonate data collected before July 1, 1990 when the laboratories were switched is poor, and of little use. Large variations in the saturation index of calcite result from apparently erroneous variations in the bicarbonate data and especially the pH data. The pH shows a number of downward trends during a five to six week interval, followed by sudden increases back to about 7.6. These increases of up to 2 pH units would be unusual in the natural system, since they do not correspond to changes in either SO_4^{2-} or HCO_3^-. They are more likely caused by wander of a pH measuring device in the lab over a number of weeks between calibrations. Several other apparent errors have been detected in Ca^{2+} and SO_4^{2-} and are shown on Figure 3. Emphasis is therefore placed on data collected since July 1, 1990.

Another major ion trend is shown in Figure 4. Magnesium tends to vary linearly with HCO_3^- (after July 1, 1990) which suggests that both are from the same source. This provides more evidence that waters from the carbonates, in particular dolomite, are included in the bulk mine waters. Figure 5 is a plot of sodium vs chloride concentrations which vary linearly suggesting a common source. The source may be river water, which contains road salt from highway run off. It may also have come from marine deposits where salt was trapped in interstitial spaces during deposition and diagenesis.

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TABLE 2 STATISTICAL SUMMARY OF WEEKLY MINE WATER DISCHARGE CHEMISTRY APRIL 12,1989 TO MAY 31, 1991

Parameter		Units	Mean	Minimum	Maximum	St. Dev.	No. of Samples
Aluminum	(Al)	(mg/L)	1.43	0.00	22.00	2.72	108
Antimony	(Sb)	(mg/L)	<0.05				30
Arsenic	(As)	(mg/L)	0.01	<0.01	0.26	0.03	105
Barium	(Ba)	(mg/L)	0.03	0.01	0.07	0.02	30
Beryllium	(Be)	(mg/L)	<0.005				30
Boron	(B)	(mg/L)	0.12	0.01	0.18	0.03	30
Cadmium	(Cd)	(mg/L)	<0.005				30
Calcium	(Ca)	(mg/L)	493.69	100.00	576.00	53.57	108
Chromium	(Cr)	(mg/L)	0.02	<0.01	0.18	0.04	30
Copper	(Cu)	(mg/L)	<0.01	<0.01	0.02	0.00	108
Iron	(Fe)	(mg/L)	1.29	<0.02	14.70	1.92	108
Lead	(Pb)	(mg/L)	0.31	<0.005	2.80	0.50	108
Cobalt	(Co)	(mg/L)	<0.01	<0.01	0.02	0.00	29
Magnesium	(Mg)	(mg/L)	16.89	2.60	30.40	5.71	107
Manganese	(Mn)	(mg/L)	0.39	0.28	0.55	0.08	30
Mercury	(Hg)	(mg/L)	<0.0002				99
Nickel	(Ni)	(mg/L)	0.01	<0.01	0.06	0.01	108
Phosphorus	(P)	(mg/L)	0.01	0.01	0.02	0.01	2
Selenium	(Se)	(mg/L)	<0.01				30
Sodium	(Na)	(mg/L)	10.43	2.06	17.00	2.29	78
Tin	(Sn)	(mg/L)	<0.30				30
Vanadium	(V)	(mg/L)	<0.01	<0.01	0.02	0.01	30
Zinc	(Zn)	(mg/L)	0.39	<0.01	4.91	0.63	108
Ammonia-N	(NH4)	(mg/L)	<0.05				2
Nitrate	(NO3)	(mg/L)	0.40	<0.05	1.65	0.48	30
Nitrite	(NO2)	(mg/L)	<0.05				30
O-Phosphate	(PO4)	(mg/L)	<0.01	<0.01	0.33	0.06	28
Carbonate	(CO3)	(mg/L)	0.16	0.00	1.74	0.28	79
Bicarbonate	(HCO3)	(mg/L)	109.24	26.80	171.90	25.07	79
Sulphate	(SO4)	(mg/L)	1205.73	620.00	1420.00	106.04	108
Total Organic Carbon		(mg/L)	1.70	<0.5	39.00	3.69	107
Chloride	(Cl)	(mg/L)	11.62	6.89	20.00	2.35	108
Fluoride	(F)	(mg/L)	<0.01				30
Hardness		(mg/L)	1321.61	1120.00	1506.80	95.31	76
Spec. Conduct.		(umhos/cm)	2416.48	1200.00	4000.00	716.42	108
Color		TCU	33.75	<2.0	500.00	65.90	107
Turbidity		NTU	106.62	9.00	>1000	120.41	108
Total Suspended Solids		(mg/L)	280.62	1.00	2320.00	410.21	106
pH		(units)	7.41	6.29	8.25	0.39	108
Alkalinity		(mg/L)	93.24	22.00	141.00	17.53	108
Oil and Grease		(mg/L)	2.74	<1.0	280.00	26.94	107

Note: From Westminer Canada Ltd. data base file GRH20SM5.WK1, Gays River Mine Weir Pond.

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TABLE 3 STATISTICAL SUMMARY OF WEEKLY TAILINGS POND DISCHARGE WATER CHEMISTRY

Parameter	Units	Mean	Maximum	Minimum	No. of Samples	St. Dev.
Suspended Solids	(mg/L)	3.69	18.8	1.0	575	1.72
pH	(units)	7.23	8.1	6.0	575	0.40
Sulfate	(mg/L)	616.43	1270	8.4	120	372.16
Arsenic	(mg/L)	0.03	0.23	<0.005	120	0.03
Iron	(mg/L)	0.12	1.00	0.01	120	0.14
Copper	(mg/L)	0.02	0.08	<0.01	120	0.01
Lead	(mg/L)	0.03	0.36	<0.01	120	0.03
Zinc	(mg/L)	0.06	0.72	<0.01	120	0.10
Nickel	(mg/L)	0.02	0.12	<0.01	120	0.01
Aluminum	(mg/L)	0.12	0.45	<0.05	120	0.10
Mercury	(ug/L)	0.05	0.20	<0.02	85	
Calcium	(mg/L)	271.02	660.00	77.00	47	162.43
Magnesium	(mg/L)	16.57	51.00	5.20	47	10.44
Sodium	(mg/L)	6.01	29.40	0.94	15	7.47
Potassium	(mg/L)	1.32	3.82	2.70	15	1.25
Organic Carbon	(mg/L)	3.89	16.00	<0.5	120	2.37
Oil & Grease	(mg/L)	0.75	1.00	<0.5	120	0.25
Cyanide	(mg/L)	0.01	0.08	<0.05	13	0.02
Ammonia	(mg/L)	0.10	0.50	<0.05	47	0.11

Data based on WCI-H202.WK1. Monitoring Point WCI-GR1.

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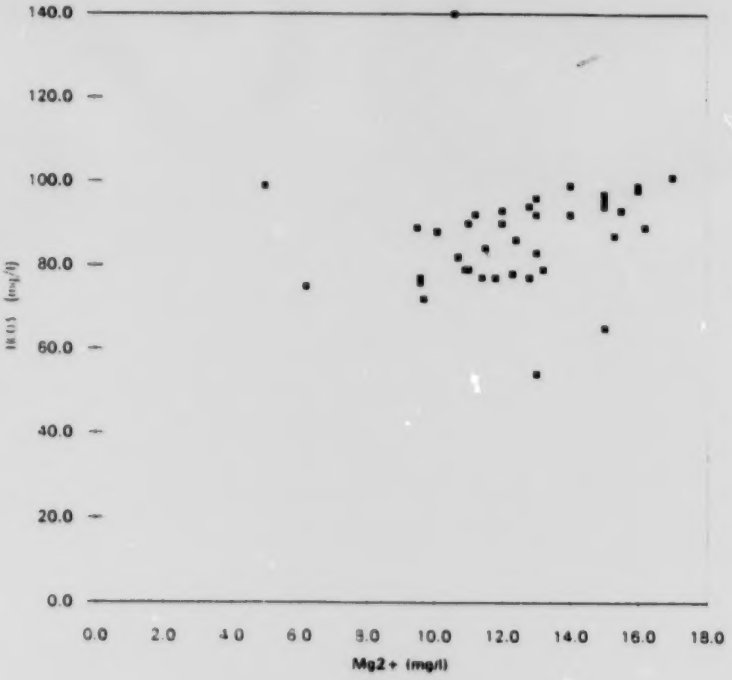
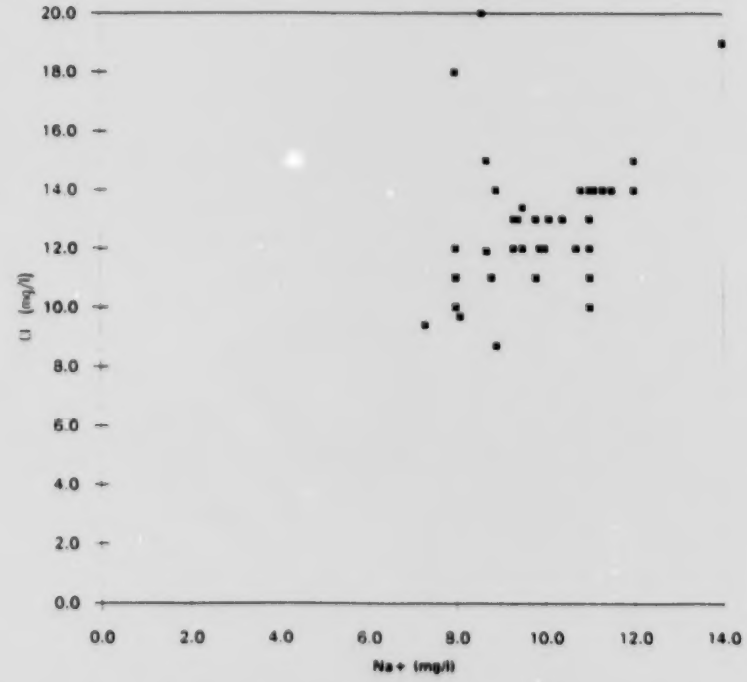


COMPARISON OF MAGNESIUM AND BICARBONATE CONCENTRATION IN MINE DISCHARGE WATER AFTER JULY 1990



COMPARISON OF SODIUM AND CHLORIDE CONCENTRATIONS IN MINE DISCHARGE WATER SINCE JULY 1990

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FIGURE 4 & 5

The major ion data from the tailings pond discharge is incomplete. The most complete data is for SO_4^{2-} which shows a range from 1200 mg/L in summer to 400-600 mg/L in winter. These variations are likely a result of significant changes in the input of surface runoff into the tailings pond catchment.

From the available data, Ca^{2+}, Mg^{2+} and Na^{+} have ranges similar to those in mine waters. The pH in the tailing pond discharge appears to be cyclic and varies over 1.5 pH units with high values in the summer and low values in the winter. This pH lowering may be due to increased CO_2 dissolved in the cool winter water, or seasonal mixing with surface water.

2.2.2 Trace Element Data

The trace elements Al, As, Cu, Fe, Pb, Ni, Zn and F were analyzed continuously during the period of monitoring. A partial record of Sb, Ba, Be, B, Cd, Cr, Co, Mn, Hg, P, Se, Sr, Sn, Ti, V, NH_4, NO_3, NO_2, PO_4 and CO_3 was also kept but most of these had very low or undetected values (Table 2). In addition to this, turbidity, suspended solids, conductivity, Total Organic Carbon (TOC), colour and total oil and grease were also monitored. The metals data cannot be considered a reliable indication of dissolved species because samples were not field filtered and, as a result, include the metal content of suspended matter. They do, however, show some interesting trends which are outlined below.

Both Pb and Zn in mine waters show a steady increase since 1989. This correlates with an increase in both turbidity and suspended solids as mining activity progressed. Figure 6 shows Zn and turbidity in mine waters from 1989 to present. The increasing concentration of metals results from dissolution of metals associated with suspended matter when the sample is acid digested in the laboratory. This can be prevented by pressure filtering with a 0.45 micron filter in the field during the sampling procedure.

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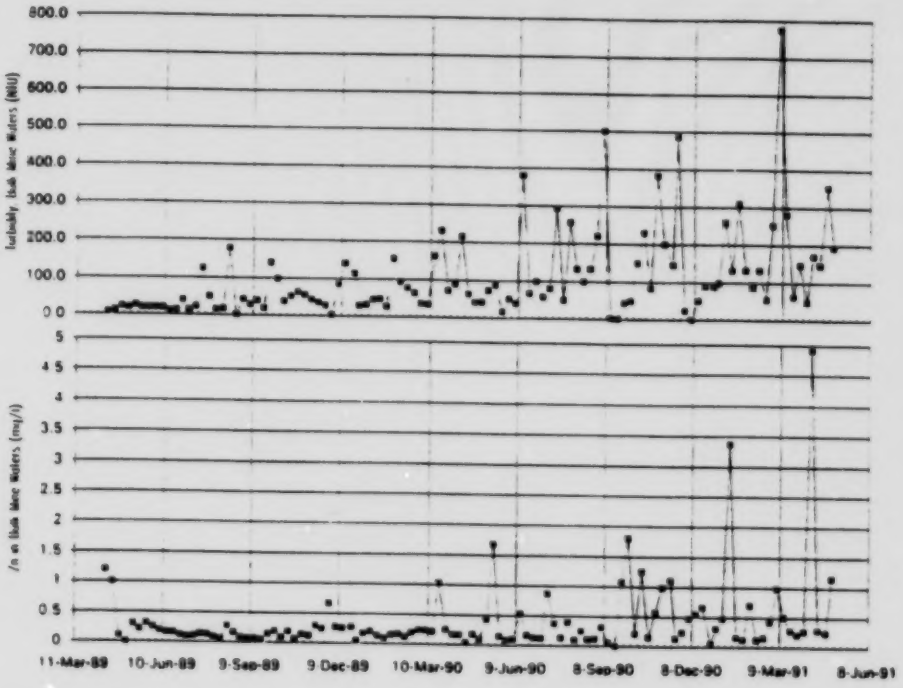
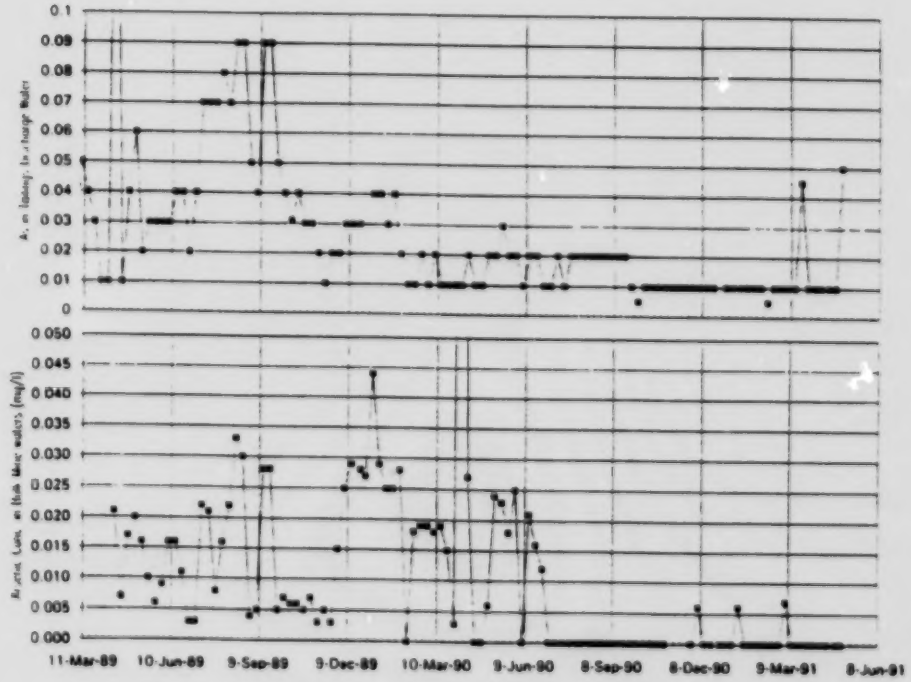


DISTRIBUTION OF ZINC AND TURBIDITY CONCENTRATIONS WITH TIME IN MINE DISCHARGE WATER



TEMPORAL VARIATION IN ARSENIC CONCENTRATION IN MINE WATERS AND TAILINGS POND EFFLUENT

240 89/01

FIGURE 6 & 7

An increase in Zn similar to the one noted in the mine waters is also seen in the tailings water effluent. This, however, is not due to an increase in suspended matter because its level has remained steady at about 6 mg/L. Zn is one of the more soluble metals and thus would be expected to rise as milling operations progressed. The probable source is the $ZnSO_4$ which is used in the concentration operations. If mine water samples had been filtered, Zn may have been a useful tracer element to help determine the percentage of river water entering the mine. Unfortunately, levels in the suspended matter in mine waters are much higher than those in the tailings effluent.

A good correlation does exist between As in tailings effluent and mine waters. Figure 7 shows at least seven points before July 1, 1990 where the correlation between As in these two records is very good. Arsenic is often associated with gold ore and therefore we have concluded that it probably entered the tailings lagoon during gold milling operations. To our knowledge, there is no natural source of As in the mine. Whatever its source, arsenic appears to have left the tailings pond in dissolved form, entered the river and was subsequently carried into the mine by river waters. Dilution must have occurred both as it entered the river and as river waters entered the mine, but even with this, the levels at the seven times where correlation is apparent indicate a dilution factor ranging between only one and three. This would suggest that a large component of mine water originated from the river during these periods. Using the As data, river flow rates and tailings water discharge rates, calculations could be made to determine the approximate As concentration in river water. This, in turn, could be used to calculate the amount of river water in the mine for each period that As values correlate in both data sets.

Considering the major ion record during this period and the fact that As levels apparently drop off in both data sets at the time the labs are changed (July 1, 1990), a systematic analytical error could also explain the phenomenon. However, it is expected that the sudden drop-off is due to analytical methods with different

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sensitivities used at each lab. The tendency for the tailings waters to be consistently higher in As than the mine waters (except in three isolated cases) suggests that As is at least detectable at levels which are relatively high or low using the analytical method of the first lab. The lower limit of arsenic detection was 0.005 mg/L (or 0.01 mg/L when rounded to the next significant digit after June 1990).

2.3 Conclusions

The major ion chemical data gathered by Westminer since 1989 show that changes over time in the bulk mine water chemistry are a result of changes in the relative proportion of surface water entering the mine. The greatest changes occur during periods of high water levels and high rainfall. Such information suggests good hydraulic connection between the surface and the mine.

Trace element data, in particular As and Zn, also indicate a connection with river water. Changes in concentrations of As in the tailings pond discharge correlate well with changes in As concentration in the mine waters. Future work should include calculations based on this data combined with tailing pond discharge rates and river flow rates to determine proportion of surface water flow.

Magnesium plotted against bicarbonate (HCO_3^{-}) shows a linear relationship. This suggests that most magnesium originates in the carbonate rocks, probably in dolomite. Therefore, the concentration of Mg^{2+} could be useful in determining the percentage of mine water originating in the carbonate. A similar relationship is noted for some wells in the spatial data set.

Serious problems exist with the quality of the data before July 1, 1990. Apparent systematic errors in the analytical procedures which determined pH and bicarbonate (alkalinity) have resulted in data which is questionable.

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3.0 1991 HYDROCHEMICAL SURVEY

3.1 Introduction

A baseline mine water sampling program was designed based on the review of available data. The objective was to identify aqueous geochemistry variations that could be used to (a) identify mine water recharge pathways, and (b) be useful for long term mine water monitoring strategies.

The main consideration of the sampling program was the selection of suitable sampling locations that would be representative of the various water types and suspected sources involved. This selection was determined through interpretation of existing data, inspection of the mine workings and dialogue with Westminer personnel.

The field sampling component of the study was carried out over a period of 11 days between June 10 and June 28, 1990, by a two-person team consisting of a JWEL hydrogeologist and a mining engineer familiar with the mine site. Field work involved:

* in-situ measurement of sensitive hydrochemical parameters (pH, temperature, Eh, electrical conductance and dissolved oxygen) in selected boreholes and drain holes located throughout the mine workings;

* sampling of underground mine water inflows for analysis of major ion, metal and isotope chemistry, including the Westminer water pressure monitoring holes (PT-series) and major drain holes;

* profiling 12 sinkholes identified by Martec Limited on the river bottom for pH, temperature, dissolved oxygen, redox potential and electrical conductance;

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- sampling of eight deep monitoring wells used by Westminer to monitor dewatering progress;

- collection of water samples from 14 surface water stations for analysis of major ion, metal and isotope chemistry, including the compliance monitoring stations at "A" and WCI-GR1, the tailings pond and the sand pit sump;

- collection of representative bedrock samples for selected isotopic analysis.

The water quality sampling program was subdivided into a field monitoring component, utilizing state-of-art hydrochemical monitoring equipment, and a laboratory component of selected sample analysis determined from the results of the field determinations.

3.1.1 Field Monitoring Program

A Hydrolab Corporation Surveyor 3 Multi-parameter Water Quality Logging System with a H20 Multi-parameter Water Quality Data Transmitter was used to record insitu water quality data at 13 surface water sites, 33 underground stations and one deep monitor well subjected to pumping. This instrument measures temperature (degrees Celsius), pH, conductivity (millisiemens), redox potential (millivolts), dissolved oxygen (mg/L and %), and TDS (g/L). These parameters can be measured by either submersing the sensing unit in the sampling medium such as a river, lake, monitor well or bucket containing the liquid; or by attaching a hose to a flowing source such as a borehole and allowing the liquid to run through a flow cell which surrounds the sensors. The unit was calibrated with standards prior to use, and checked daily.

3.1.2 Sampling Procedures

A total of 33 underground samples were collected by direct connection to the flowing boreholes or drain holes where possible. These samples provide the most

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representative data on dissolved oxygen, pH and Eh. The remaining, less accessible sites were sampled by collection of water in a bucket, and immediate measurement of sensitive parameters, field filtration for metals, and storage in appropriate bottles.

A total of eight deep monitoring wells were sampled for characterization of water chemistry. Two wells were pumped with a submersible pump and the remaining wells were bailed with a polyethylene bailer due to extreme depth to water (> 90m).

A total of 14 stream samples were collected from a boat in the centre of each stream at a depth of 1 m. A sample was collected from the centre of the tailings pond by bailing from 1.5 m, and from the sand pit sump.

All samples were clearly labelled in the field, placed in protective shipping containers and transferred directly to the laboratory. For logistical reasons, all stations were sampled for all parameters; those sub-samples not analyzed during this investigation will be retained at JWEL for a period of 6 months, after which they will be discarded, unless directed otherwise by the client.

3.1.3 Analytical Procedures

All inorganic chemistry analysis was performed by Fenwick Laboratory Limited of Halifax, Nova Scotia. This lab has demonstrated a high degree of analytical QA/QC for inorganic chemistry analysis in previous studies conducted by JWEL, and provides a rapid sample turn-around compared to other labs. Analysis of major ions and other physical and inorganic parameters was performed on a total of 50 sampling locations. This analysis includes: Na, K, Ca, Mg, hardness, alkalinity, SO4, Cl, Si, O-PO4, nitrate, ammonia, TOC, Fe(t), Mn(t), Cu(t), Zn(t), colour, turbidity, pH (lab), conductance, ion sum, and calcite saturation index.

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A total of 14 selected samples from the underground stations, wells and river water were analyzed for trace metals to determine if any of these will be useful in future mine water monitoring strategies. To be comparable for interpretation, all metals samples were field filtered and preserved at the time of sampling. The metal scan includes: Al, As, Ba, Be, Bo, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Sn, U, V, Zn.

Samples from selected locations representative of possible sources and pathways (20 samples) were submitted to the University of Waterloo Environmental Isotope Laboratory for analysis of environmental isotopes (Oxygen-18, deuterium, tritium). A total of 7 samples from suspected major water sources were also analyzed for sulfur-34 and sulfate oxygen-18 isotopes; and two rock samples, a specimen of gypsum and one of sulphide, were run for sulfur-34.

3.2 Underground Monitoring Stations

A water sampling program, designed to measure specific physical and chemical parameters, was conducted within the area of the mine workings. Mine water inflows and seepage were identified by Westminer personnel prior to implementation of the sampling program. These included several major de-watering holes (118 sump and 808 drift), water pressure monitoring boreholes (PT-series samples), and random flowing boreholes and roof drippings located throughout the mine. The sample type and locations are summarized on Table 4, and are shown in plan view on Drawing 7170-2.

Sample locations were chosen to provide good coverage of both the active and old mine workings. Due to the drought conditions experienced during the study period (seven weeks with negligible rain and drawdown caused by increased flows due to underground drainhole repairs) many of the smaller flows dried up within a period of two weeks. The sample sites therefore represent the larger flows, ranging from seeps of a few litres/minute to major inflows exceeding 4000 L/min (1000 USgpm, 118 and 808 areas).

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TABLE 4 UNDERGROUND SAMPLE LOCATIONS AND DESCRIPTIONS - WESTMINER GAYS RIVER MINES

APPROXIMATE ELEVATION (m)		SAMPLE #	TYPE	HYDRO LAB ANALYSES	NOTES	MINE AREA	NORTHING	EASTING
ROOF	FLOOR							
416	412	804	B	Y	160 L/min	804 STOPE	6660	7970
433.6	430.1	807	B	Y	11 L/min	807 STOPE	6760	8070
447	444	820	B	N	5 L/min	820 STOPE	6570	7970
		856	B	N	25 L/min	856 STOPE	6810	8550
		858	B	Y	25 L/min	858E	6775	8595
454.0	449.4	863	D	Y	18 L/min	863 STOPE	7085	8665
444.9	439.8	PT-2 (U625)	D	Y	19 L/min	625	6695	8130
426.2	412.3	PT-3 (808)	D	Y	14 L/min	808 STOPE	6755	8095
		808-1	D	N	3000 L/min	808 DRIFT	6755	8095
		PT-4	-	-	Monitor (Dry)		6800	8485
		PT-5 (U641)	D	Y	Monitor (16 psi)		6790	8590
-	450	PT-6 (803)	B	Y	380 L/min	803 STOPE	6690	8020
		PT-7	D	Y	Monitor (4 psi)	101-D DRIFT	7210	8880
		PT-7A	B	N	DRILLHOLE	101 SUMP	7215	8815
427.8	422.8	PT-8	D	Y	Monitor (30 psi)	118 SUMP ACCESS	7110	8570
474.3	469.2	PT-9 (U563)	D	Y	20 psi (16 L/min)	201 DRIFT	6995	8960
449.4	444.8	W1	B	Y	56 L/min	BELOW 825 SUMP	6695	8155
450	445.5	W2	B	Y	< 5 L/min		6600	8010
476	473	W3	B	N	6 L/min	201 DRIFT	6980	8925
-	480	W4	D	Y	SEEP	POWDER MAG.	6970	8840
422.1	411.5	W5	B	N	BULK HEAD	DIRTY SAMPLE	7165	8680
		W6	B	N	2 L/min	119 AREA	7125	8690
452.1	457.3	W7	B	N	SEEP	DRIFT	7215	8775
481.5	476.1	211	B	Y	SEEP	211 DRIFT	7270	9230
454.9	449.9	212	B	Y	SEEP	212 DRIFT	7295	9180
481.4	476.1	214	B	Y	115 L/min	214 DRIFT	7295	9210
405.3	402.2	101	B	N	900 L/min	101-2 DRIFT	7190	8865
405.3	402.2	118 No. 1	D	Y	4500 L/min	118 SUMP	6995	8540
405.3	402.2	118 No. 2	D	Y	4500 L/min	118 SUMP	6995	8540
405.3	402.2	118 No. 3	D	Y	2000 L/min	118 SUMP	6995	8540
404	398	118-4	B	Y	11 L/min	118-3 BULKHEAD	6975	8510
		118-F	D	Y	~ 10 L/min	BELOW 118 SUMP	6950	8440
427.8	422.8	119-A	B	N	90 L/min	DRAINS 119 B&C	7125	8570
491.7	486.8	R-1	B	Y	ROOF SEEP	PORTAL AREA 109 DRIFT	6825	8665

Notes
B - bucket sample
D - direct connection to drill hole
Northing/Easting is Westminer mine grid
W - areas with no other stope reference, location, etc.
F - 118-F is a seepage face
PT - Westminer pressure head monitoring boreholes

TABLE 5. IN-SITU CHEMICAL MONITORING OF UNDERGROUND SITES - WESTMINER GAYS RIVER MINE

SITE	TEMP (C)	DISSOLVED OXYGEN (ppm)	TDS (mg/L)	CONDUCTANCE (Field) (uS)	CONDUCTANCE (Lab) (uS)	FIELD pH (units)	LAB pH (units)	FIELD eH (mv)	REMARKS
PT-2 (U625)	9.48	1.08	2192	3132	3540	7.55	7.4	284	Direct
PT-3 (808)	8.72	1.53	2293	3276	3040	7.53	7.5	326	Direct
PT-4									dry
PT-5 (U641)	9.23	0.25	1309	1870	1470	7.48	7.7	384	Direct
PT-6 (803)	8.26	0.25	2417	3453	3420	7.52	7.8	356	
PT-7	7.99	0.46	2480	3543	3540	7.22	7.4	391	Direct
PT-7A	8				3570		7.5		
PT-8	9.16	0.56	2226	3180	3450	7.44	7.5	360	Direct
PT-9 (U563)	8.02	0.22	1944	2777	2600	7.35	7.6	328	Direct
W1	8.8	1.43	2371	3387	3300	7.64	7.8	303	
W2	7.78	0.23	1872	2675	3300	7.61	7.8	294	
W3	7.5				2770		7.6		
W-4	9.42	0.64	795	1136	1530	7.42	7.5	450	Direct
W-5	7.5				3270		7.5		flow from bulk head
W-6	7.5				3430		7.8		
W-7	7.5				3560		7.5		
101	8				3500		7.5		
118 - No. 1	10.72	3.38	2146	3066	3230	7.55	7.6	401	Direct
118 - No.2	10.86	3.44	2187	3124	3170	7.57	7.6	375	Direct
118 - No.3	10.87	3.35	2131	3044	3210	7.57	7.5	360	Direct
118-4	9.48	6.42	2331	3330	3250	7.55	7.6	565	Bulkhead overflow
118-F	10.86	0.18	2353	3361	3670	7.68	7.6	218	Direct
119-A	9.5				3430		7.5		flow from 119B & D
211	7.76	6.20	2573	3676	3900	7.54	7.5	285	borehole
212	7.84	8.74	2612	3732	3700	7.48	7.6	437	roof seepage
214	8.25	6.67	2319	3313	3220	7.49	7.8	404	roof seepage
804	8.36	7.17	2511	3587	3650	7.59	7.5	258	
807	8.08	3.43	2302	3288	3340	7.70	7.6	253	
820	7.5				2500		7.7		
856	7.5				3300		7.7		
858	10.6	9.42	990	1414	1060	7.99	7.8	296	
863	8.78	2.72	2401	3429	3400	7.54	7.6	337	Direct
R-1	10.12	9.16	793	1133	825	8.04	7.8	433	seep from roof
DW-2	8.48	0.22	2362	3374	3450	7.69	7.8	96	Pumped 2 hr

1. Direct = direct connection of Hydrolab flow cell to flowing borehole or drainhole.
2. Other samples collected from flowing boreholes or sumps in a bucket, and immediately analysed.
3. Field sampling conducted week of June 17 to 21, 1991.
4. Refer to Drawing 7170-2 and Table 4 for sample locations and details.

All sites were measured for pH, temperature, electrical conductance, redox potential and dissolved oxygen (Table 5). Several wall seepage areas were also sampled, and measured for temperature. The Hydrolab data recorded at underground locations involved either direct connection to existing boreholes allowing water to pass through the flow cell, or collection of water in a bucket from flows coming from the roof and face, and quickly immersing the sensor in the bucket during sampling. The first method provides the most representative chemistry results of the water since the sample has very little to no exposure to the atmosphere. Good estimates of pH,conductance and temperature are provided from the bucket samples, however, redox potential and dissolved oxygen concentrations are expected to be somewhat higher than true values due to contact with the atmosphere, and are interpreted accordingly.

3.2.1 Temperature Distribution

Temperature of individual flowing boreholes could be a useful indicator of water source. For example, groundwater in Nova Scotia generally averages seven to eight degrees Celsius year round. Thus colder water in winter/spring or warmer water in summer/fall could indicate a surface connection.

Temperatures were measured in all stations both underground and above ground (Tables 5 and 14). The surface water temperature during the study period averaged 20.3 degrees Celsius, with a small variation of 2 degrees and a standard deviation of 0.9 °C. The underground waters averaged 8.7 degrees, with a range of 7.5 to 10.9 degrees and a standard deviation of 1.1 degree C. Significant temperatures (>10 degrees) were observed in the 118 drainholes, 118-F, 858 and R1, and temperatures in excess of 9.5 degrees were observed at PT2, 118-4, 119A and W4.

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3.2.2 Dissolved Oxygen

Dissolved oxygen (DO) in deep groundwater is generally low or absent due to various redox reactions that naturally occur along the flow path. The DO in the surface waters generally averaged 7.7 ppm (decreasing with depth below the surface (Table 14). Considering only direct connect sample sites, the mine water DO averages 1.3 ppm, ranging from 0.2 to 3.4 ppm. The highest concentrations were observed at the 118 sump drainholes and 863. Other sites with suspected DO include R1, 118-4, 858, 804 and 808. Presence of dissolved oxygen suggests hydraulic connection with the surface water regime, and a relatively rapid transit time of the water, however, D.O may be introduced in the pipes or pumps in some situations (e.g. 858).

3.2.3 Redox Potential

Redox potential (Eh) is a measure of the oxidation-reduction potential of the mine water. The redox potential of groundwater is expected to be lower than the surface waters (average 320 mv, Table 14). Considering the direct connection sites (Table 4), the uncorrected redox averages 324 mv for underground sites, ranging from 218 to 450 mv. Higher than average Eh is seen at the shallow portal ramp sites (R1, W4), at PT-5 located deeper in the mine, and around the 118 area (118 holes) and 119 area (PT8). The lowest Eh at 118F correlates with other evidence of reducing conditions, including the highest Na+, K+, TDS, metals, and lowest dissolved oxygen.

3.2.4 pH Distribution

Good correlation was seen between the field pH and the lab values, indicating that previous pH values (since July 1990) are valid, likely due to the high calcite concentration of the mine waters. Since surface water pH is slightly higher than groundwater pH (mean 7.8 verses 7.6), higher pH should reflect a surface water

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source. The pH averaged 7.6, but exhibited a small range of 7.2 to 8.0, standard deviation 0.17 units. Elevated pH was observed only at R1, 214 and 858, known to be recharged from surface through carbonate. Lower than average pH was noted at PT7, PT8, PT9 and W4. The pH is generally not a good indicator of mine water variation.

3.2.5 Electrical Conductance

Electrical conductance is a measure of dissolved solids concentration. Mine waters generally exhibit higher electrical conductance than surface waters. Based on the major ion chemistry, surface waters have approximately half the conductance values of mine waters. The conductance values from the field data are similar to that from the lab. A large range in conductance is observed (825 to 3900 uS, mean 3038 uS). Low conductance values (< 1500 uS) were observed at 858, W4 and R1, and < 2000 uS was observed at PT5.

3.2.6 Major Ion Chemistry

Figure 8a illustrates the distribution of major ion chemistry for the underground samples. Results of major ion chemistry and metals are presented in Table 6 and summarized on Table 7 with the surface water and deep well data. All of the underground samples are classified as calcium-sulfate types. Calcium is the dominant cation (90 %, range 71 to 96%) and sulfate is the dominant anion (88%, range 67 to 95%). Magnesium (7.7%) exceeds sodium and potassium (3%), and bicarbonate (9.7%) exceeds chloride (average 1.8%) of anions. Anions show greater variation than cations.

Based on major ion chemistry, most of the samples fall within a small area on Figure 8a, with the exception of R1, 858, and PT5. It is believed that these samples represent waters derived from or mixed with groundwater from the carbonate aquifer. These

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TABLE 6. SUMMARY OF WATER CHEMISTRY DATA FOR UNDERGROUND SAMPLES
- WESTMINER GAYS RIVER MINE JUNE 1991.

SAMPLE LOCATION SAMPLE TYPE MINE LOCATION/AREA		Units	211 Raise Seepage East	213 Raise Seepage East	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Sodium	(Na)	(mg/L)	25.5	29.3	16.2	13.4	7.8	11.2	3.9	17
Potassium	(K)	(mg/L)	2	1.9	1.5	1.2	1.2	1.2	1.5	1.4
Calcium	(Ca)	(mg/L)	526	519	457	388	225	370	114	501
Magnesium	(Mg)	(mg/L)	38.1	39.2	31.4	30.9	22	29.7	14.4	29.3
Alkalinity		(mg/L)	110	120	110	170	150	160	120	150
Sulphate	(SO4)	(mg/L)	1380	1340	1190	954	518	886	246	1180
Chloride	(Cl)	(mg/L)	20	18	15	12	10	11	4.9	16
Reactive Silica	(SiO4)	(mg/L)	16.7	16.6	15.5	12.2	9	11.8	7.4	13.3
O-Phosphate	(PO4)	(mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	(NO3)	(mg/L)	<0.05	<0.05	<0.05	0.14	1.7	0.15	0.33	0.24
Ammonia-N	(NH4)	(mg/L)	0.09	<0.05	<0.05	0.17	<0.05	<0.05	<0.05	<0.05
Color		(TCU)	<3	<3	<3	<3	5	<3	8	<3
Turbidity		(NTU)	1.47	0.28	0.85	0.5	0.19	0.18	0.34	0.87
Total Suspended Solids		(mg/L)	15.0							
Conductance		(umhos/cm)	3900	3700	3220	2770	1530	2600	825	3500
pH		(units)	7.5	7.6	7.8	7.6	7.5	7.6	7.8	7.5
Total Organic Carbon		(mg/L)	<0.5	<0.5	<0.5	0.7	0.9	0.5	1.2	<0.5
Hardness		(mg/L)	1470	1460	1270	1100	652	1050	344	1370
Bicarbonate (as CaCO3)		(mg/L)	110	120	109	169	150	159	119	150
Carbonate (as CaC (HCO3)		(mg/L)	0.33	0.45	0.65	0.63	0.44	0.6	0.71	0.44
Ion Sum (Calc. TDS)		(mg/L)	2070	2040	1790	1510	891	1420	466	1850
Langlier Index (5C)			0.31	0.44	0.56	0.49	0.13	0.44	0.07	0.43
Aluminum	(Al)	(ug/L)			15		14	15	39	
Antimony	(Sb)	(ug/L)			<2		<2	<2	<2	
Arsenic	(As)	(ug/L)			<2		<2	<2	<2	
Barium	(Ba)	(ug/L)			11		23	15	33	
Beryllium	(Be)	(ug/L)			<5		<5	<5	<5	
Boron	(B)	(ug/L)			200		20	68	9	
Cadmium	(Cd)	(ug/L)			0.9		7.3	4.2	6.9	
Chromium	(Cr)	(ug/L)			2		2	3	<2	
Cobalt	(Co)	(ug/L)			1		<1	1	<1	
Copper(t)	(Cu)	(ug/L)	<10	<10	<10	<10	<10	<10	<10	<10
Copper	(Cu)	(ug/L)			<2		4	<2	2	
Iron(t)	(Fe)	(ug/L)	<20	<20	30	<20	<20	30	40	20.00
Iron	(Fe)	(ug/L)			50		20	40	44	
Lead	(Pb)	(ug/L)			13		9	5.8	8.8	
Manganese(t)	(Mn)	(ug/L)	630	210	420	120	10	50	<10	20.00
Manganese	(Mn)	(ug/L)			470		3	26	5	
Molybdenum	(Mo)	(ug/L)			4		<2	<2	<2	
Nickel	(Ni)	(ug/L)			24		15	20	7	
Selenium	(Se)	(ug/L)			<2		2	<2	2	
Silver	(Ag)	(ug/L)			<0.5		<0.5	<0.5	<0.5	
Strontium	(St)	(ug/L)			910		1500	2500	590	
Thallium	(Th)	(ug/L)			<0.1		0.1	<0.1	<0.1	
Tin	(Sn)	(ug/L)			<2		<2	<2	<2	
Uranium	(U)	(ug/L)			2.4		2.8	5.7	2.4	
Vanadium	(V)	(ug/L)			<2		<2	<2	<2	
Zinc(t)	(Zn)	(ug/L)	90	360	90	960	3480	790	1540	270.00
Zinc	(Zn)	(ug/L)			100		3700	1500	1500	

Note: Iron(t) = total iron, unfiltered
All metals field filtered 0.45 micron size, lab preserved with H_2SO_4.

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Table 6 (cont'd)

SAMPLE NUMBER / SAMPLE TYPE / MINE LOCATION/AREA		W-5 Bore Hole 107	W-6 Bore Hole 107	W-7 Bore Hole 107	PT-7 Bore Hole 101-D	PT-7A Bore Hole 107	663 Bore Hole Central	PT-3 113 Clearcut 119	[illegible] Sump 113	[illegible]
Sodium	(Na)	6.3	7.5	24.6	13	33.5	8.6	9.5	13.9	17.7
Potassium	(K)	1.5	2	1.1	1.1	1.4	1.1	1	1.1	1.2
Calcium	(Ca)	479	501	521	521	523	529	506	501	487
Magnesium	(Mg)	13.9	20.6	12.7	19.6	16.7	14	13.7	13.9	10.8
Alkalinity		100	120	130	120	120	91	92	89	74
Sulphate	(SO4)	1200	1300	1290	1250	1270	1240	1260	1290	1130
Chloride	(Cl)	7.6	7.6	26	13	28	8.5	8.9	14	12
Reactive Silica	(SiO4)	7.9	10.6	12.1	12.2	12.1	9.9	10.1	10.1	5.5
O-Phosphate	(PO4)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	(NO3)	0.69	1	0.13	0.08	<0.05	<0.05	<0.05	0.17	0.12
Ammonia-N	(NH4)	0.52	0.66	0.06	<0.05	0.12	<0.05	<0.05	<0.05	<0.05
Color		<3	<3	<3	<3	3	<3	<3	<3	3
Turbidity		325	1.91	1.2	0.3	3.19	2.38	0.48	17.2	158
Total Suspended Solids		727							78.0	383
Conductance		3270	3430	3560	3540	3570	3400	3450	3430	3230
pH		7.5	7.8	7.5	7.4	7.5	7.6	7.5	7.5	7.6
Total Organic Carbon		<0.5	<0.5	0.6	<0.5	0.5	<0.5	0.5	<0.5	0.5
Hardness		1250	1340	1350	1380	1370	1380	1320	1310	1260
Bicarbonate (as CaCO3)		99.7	119	130	120	120	90.6	91.7	88.7	73.7
Carbonate (as CaC (HCO3)		0.3	0.71	0.39	0.28	0.36	0.34	0.27	0.26	0.28
Ion Sum (Calc. TDS)		1780	1930	1970	1900	1960	1870	1860	1900	1700
Langlier Index (5C)		0.24	0.63	0.38	0.25	0.35	0.33	0.22	0.2	0.21
Aluminum	(Al)				15					
Antimony	(Sb)				<2					
Arsenic	(As)				<2					
Barium	(Ba)				11					
Beryllium	(Be)				<5					
Boron	(B)				62					
Cadmium	(Cd)				0.6					
Chromium	(Cr)				2					
Cobalt	(Co)				1					
Copper(t)	(Cu)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Copper	(Cu)				2					
Iron(t)	(Fe)	960	40	60	50	180	<20	30	100	610
Iron	(Fe)				30					
Lead	(Pb)				7					
Manganese(t)	(Mn)	530	420	410	10	460	240	190	160	190
Manganese	(Mn)				11					
Molybdenum	(Mo)				3					
Nickel	(Ni)				29					
Selenium	(Se)				<2					
Silver	(Ag)				<0.5					
Strontium	(St)				2500					
Thallium	(Th)				<0.1					
Tin	(Sn)				<2					
Uranium	(U)				2					
Vanadium	(V)				<2					
Zinc(t)	(Zn)	100	470	390	50	160	130	70	70	40
Zinc	(Zn)				40					

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Table 6 (cont'd)

SAMPLE NUMBER SAMPLE TYPE MINE LOCATION/AREA		118-2 Drain Hole 118 sump	118-3 Drain Hole 118 sump	118-4 Bulk Head 118 sump	118-F Sump 118 sump	850 Base Hole	PT-3 U-851 Borehole	856 Bore Hole 851 Ramp	W Ba Ho W	
Sodium	(Na)	7.6	7.5	16.9	49.8	15.2	26.6	11.2	9.3	11.4
Potassium	(K)	1.1	1.2	1.2	1.2	2.9	2.9	1.1	0.9	1.3
Calcium	(Ca)	480	499	507	533	133	202	489	507	523
Magnesium	(Mg)	10.3	10.6	11.9	17.6	24.4	24.5	22	17.4	24.4
Alkalinity		74	73	72	85	140	130	79	72	98
Sulphate	(SO4)	1170	1200	1240	1290	313	404	1150	1280	1240
Chloride	(Cl)	11	13	2	68	12	14	14	11	12
Reactive Silica	(SiO4)	5.2	5.4	13	8.6	11.3	10.7	12.6	8.2	10.6
O-Phosphate	(PO4)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	(NO3)	0.07	0.13	<0.05	0.31	2.1	20	0.17	0.09	10.9
Ammonia-N	(NH4)	<0.05	<0.05	<0.05	0.11	0.29	0.23	<0.05	0.08	<0.05
Color		7	3	8	<3	<3	3	<3	<3	<3
Turbidity		75.5	73.4	12.2	0.62	30.2	0.19	0.2	0.68	53.6
Total Suspended Solids		316								
Conductance		3170	3210	3250	3670	1060	1470	3300	3300	3540
pH		7.6	7.5	7.6	7.6	7.8	7.7	7.7	7.8	7.4
Total Organic Carbon		0.5	0.6	0.7	<0.5	<0.5	<0.5	<0.5	0.7	0.5
Hardness		1240	1290	1310	1400	433	605	1310	1340	1410
Bicarbonate (as CaCO3)		73.7	72.8	71.7	84.7	139	129	78.6	71.5	97.8
Carbonate (as CaC (HCO3)		0.28	0.22	0.27	0.32	0.83	0.61	0.37	0.42	0.23
Ion Sum (Calc. TDS)		1730	1780	1860	2020	605	852	1750	1880	1930
Langlier Index (5C)		0.21	0.12	0.21	0.3	0.19	0.22	0.34	0.41	0.16
Aluminum	(Al)	58			9		17			
Antimony	(Sb)	<2			2		34			
Arsenic	(As)	<2			2		<2			
Barium	(Ba)	22			10		14			
Beryllium	(Be)	<5			<5		<5			
Boron	(B)	31			200		130			
Cadmium	(Cd)	1			0.9		1.9			
Chromium	(Cr)	2			2		2			
Cobalt	(Co)	1			2		2			
Copper(t)	(Cu)	<10	<10	<10	<10	<10	<10	<10	<10	<10
Copper	(Cu)	2			2		3			
Iron(t)	(Fe)	4950	290	20	60	240	40	<20	20	840
Iron	(Fe)	80			130		40			
Lead	(Pb)	10			59		22			
Manganese(t)	(Mn)	390	170	90	310	80	140	650	450	850
Manganese	(Mn)	27			320		140			
Molybdenum	(Mo)	2			7		33			
Nickel	(Ni)	32			30		14			
Selenium	(Se)	<2			<2		<2			
Silver	(Ag)	<0.5			<0.5		<0.5			
Strontium	(St)	1800			830		2200			
Thallium	(Th)	<0.1			<0.1		0.1			
Tin	(Sn)	<2			<2		<2			
Uranium	(U)	1.3			2.5		7.2			
Vanadium	(V)	<2			<2		<2			
Zinc(t)	(Zn)	30	80	90	60	330	140	480	390	970
Zinc	(Zn)	45			80		210			

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Table 6 (cont'd)

SAMPLE NUMBER / SAMPLE TYPE / MINE LOCATION/AREA		PT-6 Bore Hole 803-sump	804 Bore Hole West	807 Bore Hole West	PT-3 Bore Hole 808-W	Line-3 Hole-2 Aardvark 809-W	809 Bore Hole West	W-2 Bore Hole West
Sodium	(Na)	13.4	23.3	8.1	6.9	7.7	26.4	21
Potassium	(K)	0.9	1.2	0.8	0.9	0.9	1.6	1.3
Calcium	(Ca)	526	526	525	457	492	305	362
Magnesium	(Mg)	21	28.3	14	7.7	8.7	33.1	30.7
Alkalinity		91	100	82	76	53	100	96
Sulphate	(SO4)	1250	1320	1320	1080	1190	805	934
Chloride	(Cl)	16	22	12	11	11	15	14
Reactive Silica	(SiO4)		11	7.5	5.1	12	10.5	10.1
O-Phosphate	(PO4)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	(NO3)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ammonia-N	(NH4)	<0.05	0.14	<0.05	<0.05	<0.05	0.18	0.06
Color		<3	4	<3	3	9	<3	<3
Turbidity		0.12	39.7	0.6	46.8	177	0.45	1.37
Total Suspended Solids			85.0			316		
Conductance		3420	3650	3340	3040	3230	2170	2500
pH		7.8	7.5	7.6	7.5	7.5	7.6	7.7
Total Organic Carbon		<0.5	<0.5	<1	0.7	0.7	<0.5	<0.5
Hardness		1400	1430	1370	1170	1260	898	1030
Bicarbonate (as CaCO3)		90.4	99.7	81.7	75.8	52.8	99.6	95.5
Carbonate (as CaC (HCO3)		0.54	0.3	0.31	0.23	0.16	0.37	0.45
Ion Sum (Calc. TDS)		1890	1990	1940	1610	1750	1260	1430
Langlier Index (5C)		0.53	0.27	0.28	0.1	-0.03	0.16	0.31
Aluminum	(Al)	7			240			
Antimony	(Sb)	<2			<2			
Arsenic	(As)	<2			2			
Barium	(Ba)	6			21			
Beryllium	(Be)	<5			<5			
Boron	(B)	90			24			
Cadmium	(Cd)	0.9			2.2			
Chromium	(Cr)	<2			3			
Cobalt	(Co)	1			2			
Copper(t)	(Cu)	<10	<10	<10	<10	<10	<10	<10
Copper	(Cu)	<2			8			
Iron(t)	(Fe)	<20	120	20	250	1960	<20	40
Iron	(Fe)	10			380			
Lead	(Pb)	12			47			
Manganese(t)	(Mn)	340	600	160	130	270	450	590
Manganese	(Mn)	300			130			
Molybdenum	(Mo)	3						
Nickel	(Ni)	13			38			
Selenium	(Se)	<2			<2			
Silver	(Ag)	<0.5						
Strontium	(St)	2500						
Thallium	(Th)	<0.1						
Tin	(Sn)	<2			<2			
Uranium	(U)	1.1			1.7			
Vanadium	(V)	<2			<2			
Zinc(t)	(Zn)	280	260	100	190	140	720	770
Zinc	(Zn)	280			43			

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TABLE 7 STATISTICAL SUMMARY OF 1991 WATER QUALITY DATA WESTMINER GAYS RIVER MINE (FROM TABLES 6,8,13)

PARAMETER	UNITS	UNDERGROUND SAMPLES (N = 33)					DEEP WELL SAMPLES (N = 9)				GAYS RIVER MAIN SITE (N = 6)			
		MEAN	MIN.	MAX.	STD.	N	MEAN	MIN.	MAX.	STD.	MEAN	MIN.	MAX.	STD.
Sodium	(mg/L)	15.79	3.90	49.80	9.64	33	14.62	3.30	36.40	8.98	7.98	4.80	11.40	2.74
Potassium	(mg/L)	1.36	0.80	2.90	0.49	33	2.01	0.80	4.00	1.11	1.10	0.40	2.00	0.59
Calcium	(mg/L)	446.48	114.00	533.00	117.04	33	303.76	18.30	569.00	212.44	266.53	78.10	461.00	145.04
Magnesium	(mg/L)	20.53	7.70	39.20	8.61	33	7.20	0.70	20.20	6.31	10.38	3.60	19.90	6.22
Alkalinity	(mg/L)	104.45	53.00	170.00	28.20	33	38.89	1.00	110.00	37.23	43.00	23.00	61.00	14.12
Sulphate	(mg/L)	1094.24	246.00	1360.00	300.28	33	733.00	39.00	1350.00	500.77	668.75	191.00	1180.00	372.61
Chloride	(mg/L)	14.86	2.00	68.00	10.74	33	13.91	5.20	29.00	6.68	9.83	4.40	14.00	3.62
Reactive Silica	(mg/L)	10.46	5.10	16.70	2.96	32	2.91	<1.0	13.60	4.58	1.95		4.70	1.79
O-Phosphate	(mg/L)	<0.01				33	<0.01				<0.01			
Nitrate+Nitrite	(mg/L)	1.17	<0.05	20.00	3.83	33	0.01		0.06	0.02	0.16		0.39	0.17
Ammonia-N	(mg/L)	0.08	<0.05	0.66	0.15	33	0.34		1.60	0.49	0.05		0.12	0.05
Color	(TCU)	1.70	<0.05	9.00	2.75	33	22.78		49.00	14.76	8.25	4.00	13.00	3.83
Turbidity	(NTU)	31.12	0.12	325.00	67.21	33	17.53	3.20	37.50	10.41	1.01	1000.00	1.67	0.62
Conductance	(umhos/cm)	3037.73	825.00	3900.00	765.00	33	2091.11	160.00	3450.00	1246.19	1742.50	520.00	3130.00	991.62
pH	(units)	7.60	7.40	7.80	0.12	33	7.18	5.40	8.70	1.01	7.23	7.10	7.40	0.11
Total Organic Carbon	(mg/L)	0.30	<0.5	1.20	0.35	33	4.58	0.80	15.00	4.53	1.85	1.30	2.30	0.46
Hardness	(mg/L)	1199.15	344.00	1470.00	287.86	33	787.97	52.70	1460.00	551.08	707.50	210.00	1230.00	386.29
Bicarbonate (as CaCO3)	(mg/L)	104.05	52.80	169.00	28.09	33	38.62	1.00	109.00	37.03	42.93	23.00	60.90	14.09
Carbonate (as CaCO3)	(mg/L)	0.40	0.16	0.83	0.16	33	0.20	0.00	0.65	0.21	0.08	0.03	0.12	0.03
Ion Sum (Calc. TDS)	(mg/L)	1672.24	466.00	2070.00	407.50	33	1099.67	80.00	1970.00	735.79	992.25	303.00	1710.00	538.79
Langlier Index (5C)		0.29	0.00	0.63	0.14	33	-0.91	-3.90	0.65	1.26	-0.21	-0.83	0.26	0.36
Aluminum	(ug/L)	42.90	7.00	240.00	67.36	10	30				28.50	22.00	35.00	6.50
Antimony	(ug/L)	3.60	<2.00	34.00	10.15	10	<2.00				<2.00			
Arsenic	(ug/L)	0.40	<2.00	2.00	0.80	10	<2.00				1.00		2.00	1.00
Barium	(ug/L)	16.60	6.00	33.00	7.66	10	27				31.50	26.00	37.00	5.50
Beryllium	(ug/L)	<2.00				10	<2.00				0.00		0.00	0.00
Boron	(ug/L)	83.40	9.00	200.00	67.77	10	5				17.50	9.00	26.00	8.50
Cadmium	(ug/L)	2.68	0.60	7.30	2.43	10	<2.00				0.30		0.60	0.30
Chromium	(ug/L)	1.80	<2.00	3.00	0.98	10	<2.00				<2.00			
Cobalt	(ug/L)	1.10	<2.00	2.00	0.70	10	<2.00				0.50		1.00	0.50

Note: Iron(t) = total iron, unfiltered

Note: All metals field filtered 0.45 micron size, lab preserved with H2SO4.

N = Number of Samples

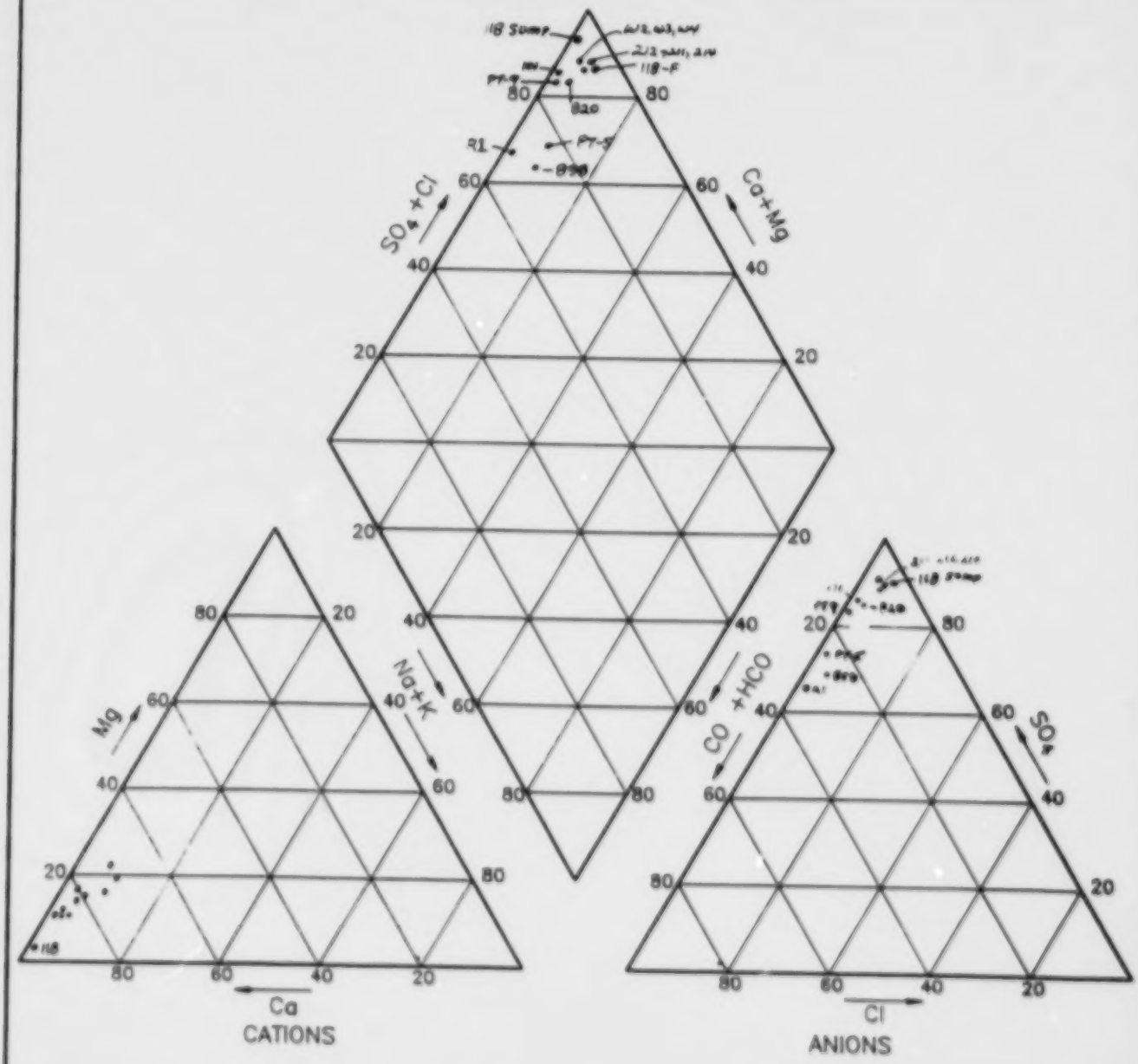
TABLE 7 STATISTICAL SUMMARY OF 1991 WATER QUALITY DATA WESTMINER GAYS RIVER MINE (FROM TABLES 6,8,13)

PARAMETER	UNITS	UNDERGROUND SAMPLES (N = 33)					DEEP WELL SAMPLES (N = 9)				GAYS RIVER SAMPLES (N = 4)			
		MEAN	MIN.	MAX.	STD.	N	MEAN	MIN.	MAX.	STD.	MEAN	MIN.	MAX.	STD.
Copper(t)	(ug/L)	<10				33	<10				15.00		60.00	25.98
Copper	(ug/L)	2.30	<2.00	8.00	2.26	10	2				2.50		5.00	2.50
Iron(t)	(ug/L)	333.33	<2.00	4950.00	903.83	33	81.31	0.07	680.00	211.84	1345.00	80.00	5100.00	2167.98
Iron	(ug/L)	82.40	10.00	380.00	104.33	10	68				21.50		43.00	21.50
Lead	(ug/L)	19.36	5.80	59.00	17.55	10	0.4				1.60	0.80	2.40	0.80
Manganese(t)	(ug/L)	295.15	0.00	850.00	216.92	33	15.79	0.04	140.00	43.91	420.00	20.00	1570.00	664.12
Manganese	(ug/L)	143.20	3.00	470.00	156.94	10	65				63.50	17.00	110.00	46.50
Molybdenum	(ug/L)	5.78	<2.00	33.00	9.86	9	<2.00				1.00		2.00	1.00
Nickel	(ug/L)	22.20	7.00	38.00	9.46	10	8				11.00	5.00	17.00	6.00
Selenium	(ug/L)	0.40	<2.00	2.00	0.80	10	<2.00				<2.00			
Silver	(ug/L)	<2.00				9	<2.00				<2.00			
Strontium	(ug/L)	1703.33	590.00	2500.00	732.80	9	880				1040.00	580.00	1500.00	460.00
Thallium	(ug/L)	0.02	0.00	0.10	0.04	9	<2.00				<2.00			
Tin	(ug/L)	<2.00				10	<2.00				<2.00			
Uranium	(ug/L)	2.91	1.10	7.20	1.87	10	1.5				0.50	0.20	0.80	0.30
Vanadium	(ug/L)	<2.00				10	<2.00				<2.00			
Zinc(t)	(ug/L)	426.97	30.00	3480.00	636.74	33	202.24		1820.00	571.97	357.50	0.00	1390.00	596.34
Zinc	(ug/L)	749.80	40.00	3700.00	1127.49	10	16				21.50	8.00	35.00	13.50

Note: Iron(t) = total iron, unfiltered

Note: All metals field filtered 0.45 micron size, lab preserved with H_2SO_4.

N = Number of Samples



GAYS RIVER HYDROCHEMICAL ASSESSMENT
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UNDERGROUND SAMPLES

FIGURE 8a

samples also exhibit the highest bicarbonate and magnesium proportions, lowest sulfate, lowest TDS, and low conductance compared to other areas. Samples from 820, 101 and PT-9 are intermediate between these two types.

A strong spatial distribution of the various parameters is seen from the chemical data. The chemical composition of the mine waters is influenced by carbonate (alkalinity, magnesium, low TDS) in the southeastern carbonate-trench contact, and by calcium and sulfate along the northwestern gypsum-trench contact. These waters are influenced to various degrees by recharging shallow groundwater possibly originating at Gays River (higher temperatures, dissolved oxygen, redox potential, and lower dissolved ions).

3.2.7 Metals Distribution

Based on the field filtered metals samples (Tables 6, 7), useful metals for future monitoring include: manganese, boron, strontium, lead and zinc. Metals are generally low, and only iron (10 to 380 ug/L, mean 82 ug/L), manganese (3 to 470 ug/L, mean 143 ug/L), lead (6 to 59 ug/L, mean 19 ug/L) occasionally exceed drinking water guidelines. Most metals species have a low solubility under the redox conditions in this mine water.

3.2.8 Discussion

The major ion chemistry of the mine is dominated by calcium sulfate waters and the major flows at 118 sump and the recent drain holes at 808. The variations in major ion chemistry are very subtle, and it is difficult to derive water sources from this data. Some conclusions can however be made based on the field monitoring work:

Several of the sites exhibit chemistry consistent with mixing with surface waters. Indicators of mixing with meteoric waters include: elevated temperature, alkalinity and

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pH, presence of dissolved oxygen, low conductance, TDS, sulfate, hardness, and calcium.

The spatial distribution of the high temperature wells with respect to the geology indicates shallow recharge water entering the carbonate-trench contact from above at PT2, 858, R1 and W4, and from the gypsum-trench contact at the 118 sump.

The waters exhibiting the greatest D.O. concentrations and highest temperature are associated with the major flows at 118, 863, 804, and 808 along the gypsum-trench contact, and R1, and 858 along the carbonate-trench contact.

Four hydrochemical facies of water chemistry can be identified within the mine complex: (1) a water type associated with mixing of shallow water and carbonate aquifer water along the southeastern carbonate-trench contact, (2) a strong calcium-sulfate type associated with the northwestern gypsum-trench contact, (3) a "diluted" calcium-sulfate type in the vicinity of the large drainholes at 118 and 808, and (4) a zone of shallow groundwater recharge in the portal-access ramp areas at R1, W4, and at 858 on the 851 decline.

Alkalinity and sulfate show the greatest degree of variation throughout the mine water samples. This variance is believed to represent variable percentages of mixing with other water types, particularly river water and surficial aquifer waters with the gypsum and carbonate aquifer water. Figure 9 illustrates the distribution of alkalinity for the 33 underground samples. The high isocontours (> 150 mg/L coincide with the trench-carbonate contact, and shallow mine areas.

All samples were found to be oversaturated with respect to calcite (positive value for Calcite saturation index, Table 6), and somewhat undersaturated with respect to gypsum as most samples were less than the gypsum solubility limit of about 1500 mg/L (see Section 2.2.1).

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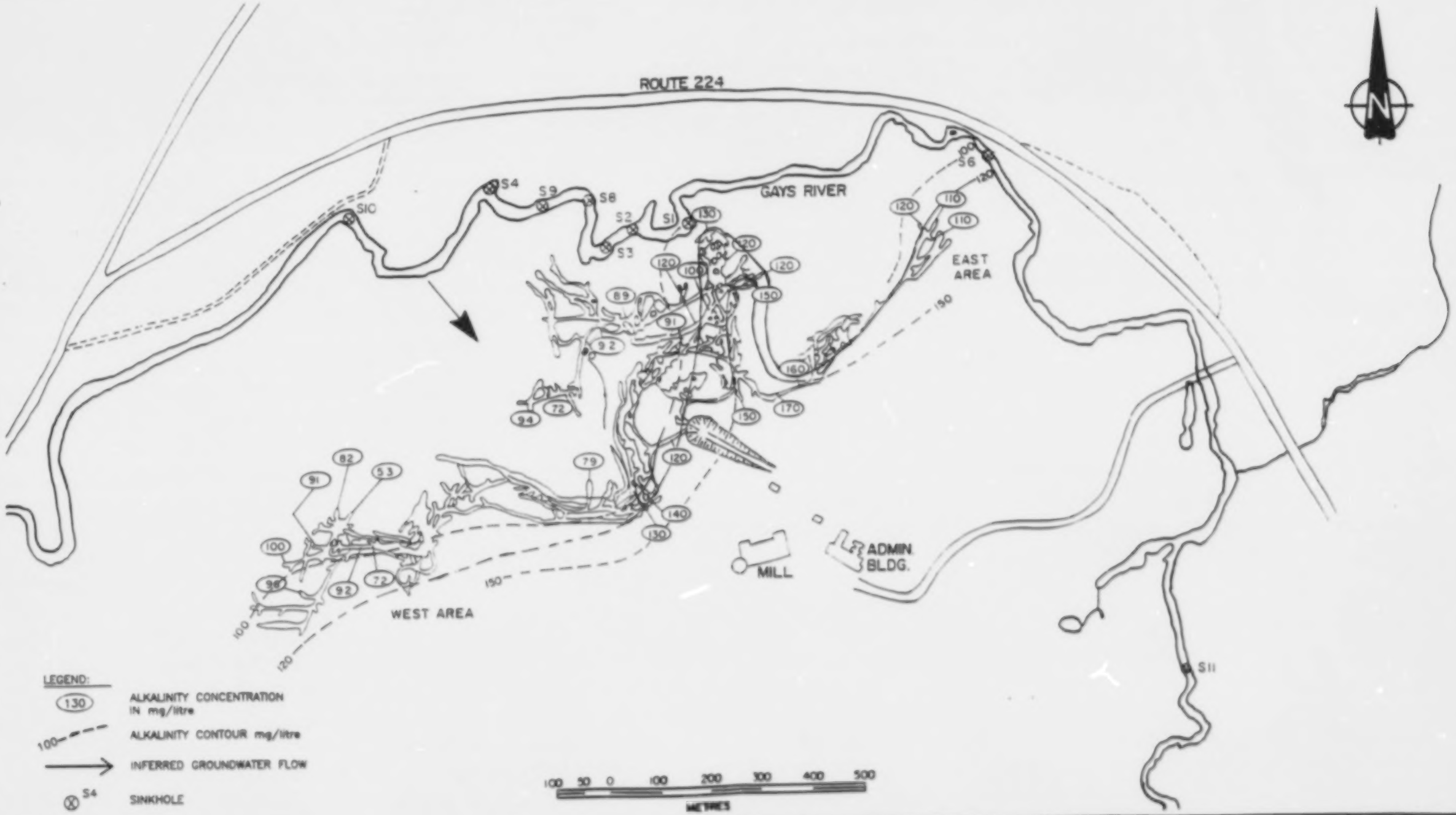

Jacques Whitford Environment Limited	REFERENCE	SCALE : AS SHOWN DATE : 91/08/02 DRAWN BY : U.M.W./G.C. APPROVED BY :	WESTMINER CANADA LIMITED GAYS RIVER HYDROCHEMICAL ASSESSMENT GAYS RIVER, HALIFAX COUNTY, NOVA SCOTIA	DISTRIBUTION OF ALKALINITY CONCENTRATIONS IN UNDERGROUND SAMPLES	DRAWING NO. FIGURE 9

With respect to mine area flow rates and geology, the chemistry indicates that most of the water is derived from gypsum aquifers along the gypsum-trench contact. In comparison to formation water chemistry (e.g. 118-F), the major flows at 118 sump and 808 drainholes are undersaturated with respect to sulfate, elevated in temperature and dissolved oxygen and exhibit lower than average TDS and alkalinity, implying a significant degree of dilution, likely derived from the river water.

The waters in the 301 area stations in the west end of the mine are dominated by gypsum waters mixed with carbonate and Meguma water. Flow rates are lower in this area, reflected in low dissolved oxygen, lower temperature and indications of more stagnant groundwater conditions (higher sodium, chloride). The flow rate many control the degree of mixing at these locations.

The waters in the east end of the mine (201 area) are characterized by carbonate waters contacting gypsum waters, resulting in oversaturation in calcite. Calcite stalagmites were noted in the 211 drift. Based on chemistry and temperature (lowest in the mine), recharge from the surface environment is expected to be slow. Considerable roof seepage was observed, however no large inflows (> 100 USgpm) were reported. A greater amount of iron staining from rusting rock bolts was also in evidence, compared to other areas.

The waters entering the portal area and shallow mine workings (above elevation 470 m), are derived from vertical recharge of shallow aquifer water and rainwater. These locations (R1, W4) exhibit high temperature, D.O., low TDS and high alkalinity. The sand pit is located above this area, and is largely de-watered by the mine operation.

The remaining areas in the 107 and 104 zones typically exhibited gypsum water type, often influenced by carbonate water. Sample 101 shows some evidence of mixing with low TDS waters.

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Samples exhibiting turbidity in excess of 50 NTU were run for suspended solids (Table 6). Elevated suspended solids (> 100 mg/L) were noted at the major flows at 118 sump drainholes 1 and 2, the new Aardvark drainholes at 808 drift, and W-5. Moderate suspended solids (75 mg/L) was noted at 119A, and 804. Low suspended solids was reported at the roof in the 211 area. Based on the turbidity, the remaining samples appear to be low in suspended solids concentrations.

The above suspended solids concentrations correlate with the range of values monitored by Westminer from February 1/91 to May 21/91 (Westminer file TSS118.WK1) at the 118 sump (drainholes 1 and 2). Excluding three high (> 1000 mg/L) values (Feb. 14, Mar 18, Apr 25) associated with drainhole plugging, suspended solids loads average 165 mg/L and 200 mg/L at drainholes 1 and 2 respectively.

3.3 Monitor Well Sampling

3.3.1 Deep Bedrock Wells

A total of eight deep bedrock/trench monitor wells (OW3, DW1, DW-2, DW-3, ETW-1, ETW-3, ETW-4, and H-5, were sampled during the course of this investigation. These wells are distributed along the strike of the trench deposits, and are monitored on a daily basis by Westminer personnel.

A total of 17 monitoring wells were available as of May 31, 1991; 13 of these had measurable water in them. Several of the 17 monitoring wells available were dry due to the mine de-watering operation (OW-1A, H-4, H-7, DDH-733, and occasionally ETW-1), and some wells declined significantly over the study period due to the increased mine drainage rate achieved at the 808 and 118 drainholes, and the record drought conditions experienced in the summer of 1991. The static water level in these wells ranged from approximately 9 to 28 m below grade in the areas remote from

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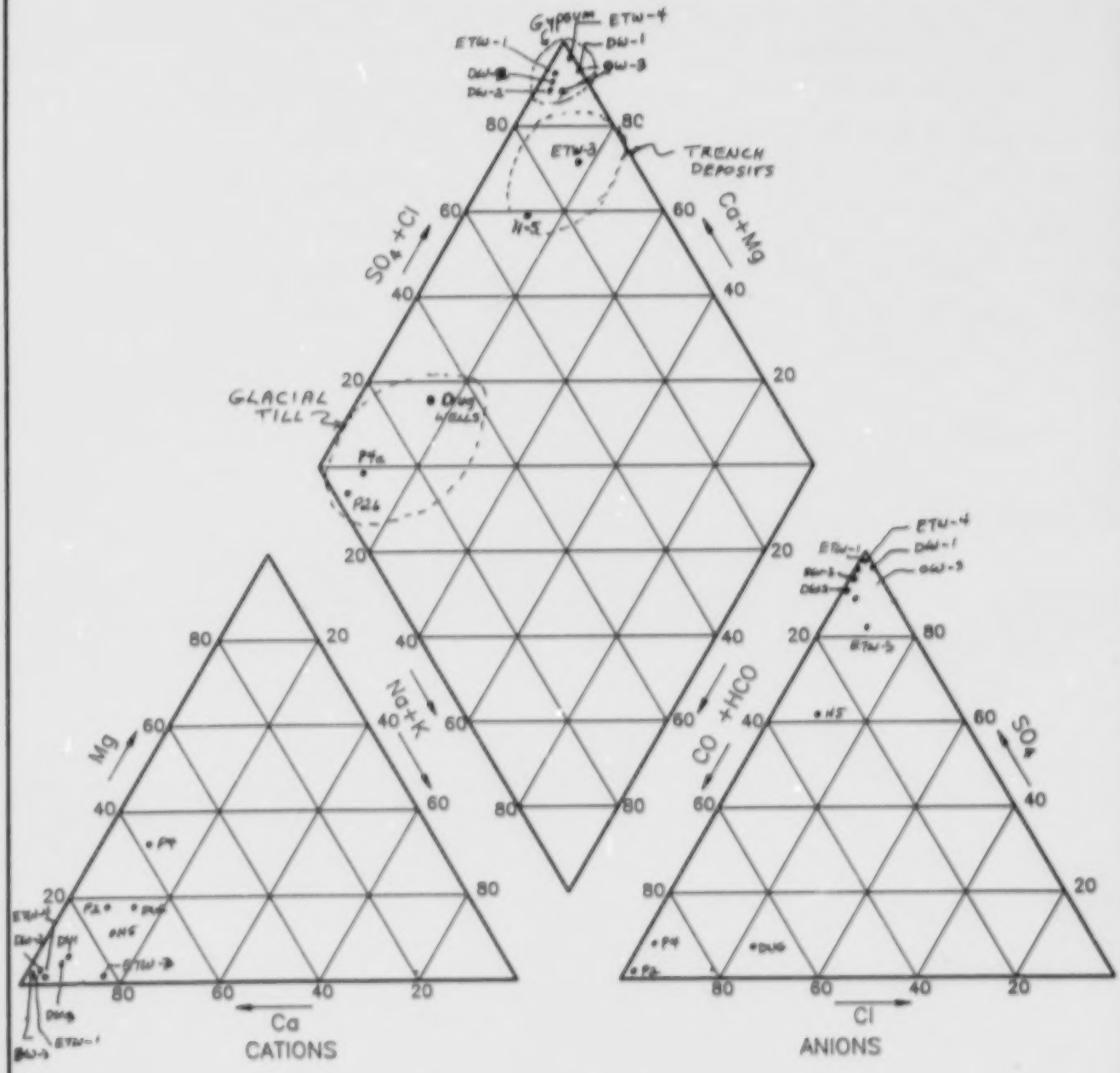

GAYS RIVER HYDROCHEMICAL ASSESSMENT
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MONITOR WELL SAMPLES

FIGURE 8b

active mine areas (OW-3, H-5) to over 90 m below grade in the central areas of the mine (ETW-1, ETW-2, H4 and DW-3).

Table 1 presents a summary of monitor well construction details generated from various Gays River References. Monitor well locations with respect to the surface and underground workings are shown on Drawing 7170-1 and 2 respectively. Results of chemical analysis are presented on Table 8, and illustrated on Figure 8b. A summary of Westminer water level data is presented on Table 9 for June 26/91.

The best water sample from a monitor well would be a sample collected after a period of pumping to remove several casing volumes and obtain a representative sample of formation water. Due to the depth to the water table, all wells except DW-2 (which was pumped) were sampled on July 23, 1991 by bailing with a 0.5 litre polyethylene bailer on 100 m of high strength fishing line. Bailed samples from depths of 90m or more provide an indication of borehole water quality, under the assumption that the rapid response of these wells to mine water pumping activities implies a good degree of hydraulic connection with the adjacent aquifer.

Monitor Well OW-3

OW-3 is screened in gypsum north of the 201 drift, and has shown 24.9 m response due to pumping. This well exhibited a dilute, calcium-sulfate type of water, indicative of surface water influence.

Monitor Well OW-2

With a water level measured at 21.15 metres, OW-2 was pumped with a 2 hp submersible pump for approximately one hour at a rate of 45.5 l/min., resulting in a water level draw-down to the pump intake at 35.1m, with no recovery observed after 24 hours; no sample was taken.

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TABLE 8 SUMMARY OF WATER CHEMISTRY DATA FOR DEEP MONITORING WELLS
WESTMINER GAYS RIVER MINE – JULY 1991

SAMPLE LOCATION		Units	OW-3	DW-1	DW-2	DW-3	ETW-1	ETW-3	ETW-4	H-5
Date Sampled			July 23	July 23	June 18	July 23	July 23	July 23	July 23	July 23
Sample Method			bailed	bailed	pumped	bailed	bailed	bailed	bailed	bailed
Depth			52.4	109.7	139.6	125	119.8	91.4	88.4	18.9
Water Level (June 26, 1991)			28.6	40.3	24.7	90.6	87.8	70.6	38.3	9.4
Geologic unit			Gypsum	Trench	Gyp-Cav	Gyp-Cav	Gyp-Cav	Trench	Gypsum	Till
Sodium	(Na)	(mg/L)	10.7	36.4	16.3	8.7	9.3	20.6	12.2	3.3
Potassium	(K)	(mg/L)	2.6	1.9	0.9	1.4	1.3	4	3.7	0.8
Calcium	(Ca)	(mg/L)	108	432	569	537	532	99	355	18.3
Magnesium	(Mg)	(mg/L)	2.8	20.2	9.9	11.8	12.2	1.3	4.2	1.7
Alkalinity		(mg/L)	21	1.0	110	77	80	27	5	19
Sulphate	(SO4)	(mg/L)	286	1080	1240	1350	1250	249	905	39
Chloride	(Cl)	(mg/L)	11	29	8	12	13	20	11	5.2
Reactive Silica	(SiO4)	(mg/L)	<0.5	< 0.5	13.6	5.7	6.9	< 0.5	<0.5	< 0.5
O-Phosphate	(PO4)	(mg/L)	<0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	<0.01	< 0.01
Nitrate+Nitrite	(NO3)	(mg/L)	<0.05	< 0.05	0.06	<0.05	< 0.05	< 0.05	<0.05	< 0.05
Ammonia-N	(NH4)	(mg/L)	<0.05	0.12	0.09	<0.05	< 0.05	1.60	0.45	0.16
Color		(TCU)	17	47	< 3	17	17	17	49	24
Turbidity		(NTU)	6.34	27.3	3.2	37.5	15	21.6	23.2	15.7
Conductance		(umhos/cm)	790	2980	3450	3430	3400	1740	2280	160
pH		(units)	6.6	5.4	7.8	7.5	7.6	7.5	5.7	7.8
Field Temperature	(C)		12.0	11.0	8.5	16.0	12.0	14.0	13.2	13.0
Total Organic Carbon		(mg/L)	2.6	2.1	0.8	1.3	1.1	8.7	7.2	2.4
Hardness		(mg/L)	281	1160	1460	1390	1380	253	904	52.7
Bicarbonate (as CaCO3)		(mg/L)	21	1.0	109	76.8	79.7	26.9	5	18.9
Carbonate (as CaCO3)	(HCO3)	(mg/L)	0.01	0	0.65	0.23	0.30	0.08	0	0.11
Ion Sum		(mg/L)	434	1600	1920	1970	1870	412	1290	80
Langlier Index (5C)			-1.91	-3.9	+0.65	+0.16	+0.28	-0.94	-2.97	-1.47
Aluminum	(Al)	(ug/L)	30							
Antimony	(Sb)	(ug/L)	<2							
Arsenic	(As)	(ug/L)	<2							

Note: Iron(t) = total iron, unfiltered
Note: All metals field filtered 0.45 micron size, lab preserved with H2SO4.

TABLE 8 SUMMARY OF WATER CHEMISTRY DATA FOR DEEP MONITORING WELLS
WESTMINER GAYS RIVER MINE – JULY 1991

SAMPLE LOCATION		Units	OW-3	DW-1	DW-2	DW-3	ETW-1	ETW-3	ETW-4	H-5
Date Sampled			July 23	July 23	June 18	July 23	July 23	July 23	July 23	July 23
Sample Method			bailed	bailed	pumped	bailed	bailed	bailed	bailed	bailed
Depth			52.4	109.7	139.6	125	119.8	91.4	88.4	18.9
Water Level (June 26, 1991)			28.6	40.3	24.7	90.6	87.8	70.6	38.8	9.4
Geologic unit			Gypsum	Trench	Gyp-Cav	Gyp-Cav	Gyp-Cav	Trench	Gypsum	Till
Barium	(Ba)	(ug/L)	27							
Beryllium	(Be)	(ug/L)	<5							
Boron	(B)	(ug/L)	5							
Cadmium	(Cd)	(ug/L)	<0.5							
Chromium	(Cr)	(ug/L)	<2							
Cobalt	(Co)	(ug/L)	<1							
Copper(t)	(Cu)	(ug/L)	<10	< 0.01	< 0.01	0.01	< 0.01	0.02	<0.01	< 0.01
Copper	(Cu)	(ug/L)	2							
Iron(t)	(Fe)	(ug/L)	680	22.5	0.07	1.1	2.5	2.34	21.8	0.75
Iron	(Fe)	(ug/L)	68							
Lead	(Pb)	(ug/L)	0.4							
Manganese(t)	(Mn)	(ug/L)	140	0.32	0.33	0.07	0.04	0.19	0.94	0.15
Manganese	(Mn)	(ug/L)	65							
Molybdenum	(Mo)	(ug/L)	<2							
Nickel	(Ni)	(ug/L)	8							
Selenium	(Se)	(ug/L)	<2							
Silver	(Ag)	(ug/L)	<0.5							
Strontium	(St)	(ug/L)	880							
Thallium	(Th)	(ug/L)	<0.1							
Tin	(Sn)	(ug/L)	<2							
Uranium	(U)	(ug/L)	1.5							
Vanadium	(V)	(ug/L)	<2							
Zinc(t)	(Zn)	(ug/L)	1820	< 0.01	0.01	0.02	0.03	0.03	0.03	< 0.01
Zinc	(Zn)	(ug/L)	16							

Note: Iron(t) = total iron, unfiltered

Note: All metals field filtered 0.45 micron size, lab preserved with H_2SO_4.

TABLE 9 GAYS RIVER GROUNDWATER MONITORING MEASUREMENTS – June 26/91
(Measurements By: S. Faulkner & T. Lamb, Westminer Canada Limited)

HOLE	COLLAR ELEVATION (metres)	MEASUREMENT (metres)	GROUNDWATER ELEVATION (metres)	DIFFERENCE SINCE LAST MEASUREMENT 19-Jun-91	TOTAL DRAWDOWN (metres)
OW-1A	518.21	dry@ 42.5	dry@ 475.71	0.00	-39.13
OW-2	522.36	35.05	487.31	-13.94	-30.02
OW-3	519.44	28.58	490.86	0.08	-24.78
OW-6	544.98	23.21	521.77	0.00	-0.91
DW-1	518.47	40.32	478.15	-0.04	-37.07
DW-2	525.29	24.74	500.55	0.02	-14.69
DW-3	530.52	90.56	439.96	-0.34	-70.98
ETW-1	535.22	dry@ 87.85	dry@ 447.37	0.05	-66.53
ETW-2	542.81	91.56	451.25	-1.06	-59.82
ETW-3	546.67	70.61	476.06	-0.01	-36.87
ETW-4	521.13	38.32	482.81	-0.07	-32.72
H-4	550.05	dry@ 91.76	dry@ 458.3		-56.01
H-5	515.27	9.35	505.92	-0.07	-9.15
H-7	519.35	dry@ 43.47	dry@ 475.88		
DDH 733	546.09	dry@ 59.92	dry@ 486.17		-25.00
DDH 738	549.59	76.68	472.91	0.01	-41.33
DDH 817	531.80	64.51	467.29	-1.74	
Mine Water			393.00	0.00	-121.63
Gays River	519.69	4.49	515.20	-0.01	-0.67

Average 7 day Pump Rate 4,250 USGPM *

* Incudes Estimated Discharge from 825 Sump and Sandpit consumption.
Note: Pump test conducted in OW-2, and well is not responsive.

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Monitor Well DW-1

DW-1 (110 m deep) is screened in trench deposits of weathered limestone and clay breccia and has exhibited 37.1m of drawdown response to mine dewatering. The water level in well DW1 was measured at a depth of 40.3 metres which was too deep for the pump to be used for sampling. Water sampling from the well was difficult because of the iron scale which had formed on the casing and continuously fell into the bailer resulting in a poor seal with the ball/sample tube and a loss of sample. The well was resampled by bailing on July 23, 1991. This well exhibited a low pH and alkalinity, and a chemistry consistent with stratified surface waters. This may be due to its location near the river and several sinkholes, or lack of well development.

Monitor Well DW-2

DW-2 (139 m deep) is open to evaporite deposits and responded 14.7 m to dewatering of the 101 area. With a water level measured at 24.74 metres, monitor well DW2 was pumped 2 hours at 45.5 l/min. The submersible pump was set at a depth of 36.5 metres. A total of 0.1 metres of drawdown attributed to well loss was observed during the two hour test, this implies a higher potential well yield (>45 L/min). The water chemistry was monitored with the Hydrolab during the pumping (Table 5), and water samples were collected prior to the completion of the pumping.

This is considered to be a good quality sample site, indicating typical gypsum formation waters, with average temperature (8.5 degrees C), low D.O. (0.22 ppm) and Eh (96 mv), and high TDS and conductance. Minor evidence of mixing with surface waters is indicated by slightly elevated alkalinity and slightly depressed sulfate concentration.

Recycled Paper

Monitor Well DW-3

DW-3 (125 m deep) is completed in gypsum cavities from 83 to 88 m depth in the 118 area. This was a high flow dewatering well, which has responded 71 m to mine water pumping; water level is now 90.6m below ground (Table 9). The chemical data indicates a strong calcium-sulfate gypsum water with little evidence of mixing with surface waters.

Monitor Well ETW-1

ETW-1 (120 m deep) was intended to be a dewatering well in conjunction with DW-3; ETW-1 is accessible to only 88 m, and is presently dry at the 447.4 m level with 66.5 m of drawdown reported. This well is completed as an open hole below 50 m in gypsum cavities south of the 118 area. A sampled bailed from this well indicates a typical gypsum water facies, similar to DW-3.

Monitor Well ETW-3

ETW-3 (91 m deep) is completed in trench deposits near the Western "C" ore zone. A moderate water producer (1500 L/min), this well has responded 37 m to mine pumping, and has a water level at 71 m below ground. The water quality is a calcium-sulfate type, with considerably less TDS than the bedrock aquifers.

Monitor Well ETW-4

ETW-4 (88 m deep) is completed as an open hole below 82 m in gypsum bedrock, located in the vicinity of Taylors Pond sinkhole. The pond is presently dry, but is reported to temporarily fill with water during rain storms in the spring and fall. The well has responded about 33 m to mine pumping, and has a water level 38 m below grade. The bailed water sample indicates stratification of shallow meteoric water

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above deeper gypsum waters (low pH and alkalinity, elevated iron from the casing, etc.) Recharge of meteoric water is suspected in this area.

Monitor Well H-5

H-5 (19 m deep), located east of the 201 area near Gays River, is open to overburden above the trench, and has responded a total of 9.15 m of drawdown. The chemistry indicates a relatively dilute (TDS 80 mg/L) calcium-sulfate-bicarbonate water considered to be typical of shallow trench deposits.

3.3.2 Shallow Monitoring Wells (WCI-GR-P1 to P6)

In addition to the deep wells located in gypsum and trench deposits, a series of shallow boreholes were sampled by Westminer personnel on June 20, 1991 as part of their environmental monitoring program. A summary of these results are shown on Table 10, and locations are shown on Drawing 7170-1.

The samples are highly turbid, due to lack of development, and were not filtered at time of collection, rendering the metals useless for interpretation, since concentrations will reflect turbidity. These hard, alkaline calcium-bicarbonate waters generally exhibit lower dissolved ions, TDS, pH and much higher alkalinity than the deeper mine waters, and the shallow overburden wells closely resemble the domestic dug wells in chemical composition. Some of the high alkalinity seen along the trench-carbonate contact, especially in shallow mine water samples at the portal, likely originates from the surficial aquifer.

3.3.3 Domestic Wells (Background conditions)

A total of 38 properties located within 1500 meters of the Westminer Canada mine/mill property were surveyed between January 10 and 15, 1990 by Porter Dillon

TABLE 10
WESTMINER CANADA LIMITED GAYS RIVER MINE QUARTERLY WATER SAMPLING RESULTS FOR SHALLOW MONITOR WELLS

Parameter	WCI-GR-P1 Surficial 20-Jun-01	WCI-GR-P1 Bedrock 20-Jun-01	WCI-GR-P2 Surficial 20-Jun-01	WCI-GR-P2 Bedrock 20-Jun-01	WCI-GR-P3 (A) 20-Jun-01	WCI-GR-P3 (B) 20-Jun-01	WCI-GR-P4 Surficial 20-Jun-01	WCI-GR-P4 Bedrock 20-Jun-01	WCI-GR-P5 Surficial 20-Jun-01	WCI-GR-P5 Bedrock 20-Jun-01	WCI-GR-P6 Surficial 20-Jun-01
Sodium	8.2	8.3	7.9	12.3	8.5	9.8		25.8			8.5
Potassium	0.8	0.7	0.8	1.1	3.9	1.1		2.3			1
Calcium	117	116	61.1	60.2	143	126		140			104
Magnesium	15.4	13.8	8.9	9.5	24.4	17.7	Dry	45.8	Dry	Dry	8.5
Alkalinity (as CaCO3)	190	200	210	170	310	220		540			93
Sulfate	196	185	4	10	181	188		39			245
Chloride	8.1	8.4	3.1	3.1	9.5	6.9		4.9			7.2
Reactive Silica	16	16	15	12	14	13		17			8.3
Ortho Phosphate (as P)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01			<0.01
Nitrate + Nitrate (as N)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		0.06			0.36
Ammonia (as N)	1.8	1.9	0.12	<0.05	0.22	0.04		<0.05			<0.05
Iron	5.9	6.7	2.02	0.38	33.5	1.02		3.45			1.14
Manganese	2.85	1	0.22	0.05	29.3	0.12		2.23			0.18
Copper	<0.01	<0.01	<0.01	<0.01	0.12	<0.01		0.05			<0.01
Zinc	0.05	<0.01	0.03	<0.01	0.19	<0.01		0.15			<0.01
Color (TCU)	37	20	6	9	11	5		6			3
Turbidity (NTU)	281	38	78	190	>1000	252		643			348
Spec. Conductance (umhos/cm)	845	800	380	380	990	920		1170			730
pH (units)	6.9	6.8	7.5	7.7	7.2	7.6		7.3			7.2
Total Organic Carbon	3.4	3.3	0.6	0.7	2.2	1.1		1.4			0.7
Hardness (as CaCO3)	356	344	189	185	458	387		536			284
Bicarbonate (as CaCO3)	190	200	209	169	310	219		539			52.9
Carbonate # (as CaCO3)	0.14	0.12	0.62	0.8	0.46	0.82		1.01			0.08
Ion Sum	474	445	227	200	551	495		580			411
Theoretical Conductivity (umhos/cm)	887	816	406	366	1030	915		1140			750
Cation Sum (meq/L)	7.52	7.3	4.15	3.86	9.63	8.2		11.9			5.99
Anion Sum (meq/L)	8.05	7.58	4.37	3.7	9.82	8.5		11.8			6.38
% Difference	3.37	1.9	2.53	2.11	0.96	1.81		0.77			3.19
Langelier Index (5 C)	-0.62	-0.70	-0.23	-0.21	-0.03	0.17		0.3			-0.82
Saturation pH (Units)	7.52	7.5	7.73	7.91	7.23	7.43		7			8.12

All values in mg/litre except as noted

TABLE 11 STATISTICAL SUMMARY OF DOMESTIC WATER WELL CHEMISTRY, JANUARY 1990 (PORTER DILLON LTD. FOR WESTMINER).

PARAMETER		DUG WELLS IN SILTY GLACIAL TILL (N=30) WITHOUT SOFTENERS				DRILLED WELLS IN GYPSUM (N=2)		
		MAXIMUM (mg/L)	MINIMUM (mg/L)	MEAN (mg/L)	STANDARD DEVIATION	MAXIMUM	MINIMUM	MEAN
DEPTH	(m)	7.01	2.74	4.85	1.17	91.4	?	-
DIAMETER	(m)	2.61	0.61	1.05	0.41	0.15		
CASING STICKUP	(m)	1.28	0.00	0.53	0.31			
WATER LEVEL	(m BTOC)	4.43	0.50	2.27	0.99			
	(m BGL)	4.22	0.26	1.76	1.06			
Sodium	(mg/l)	72.00	1.90	15.87	20.04	47	13	30.0
Potassium	(mg/l)	7.70	0.30	2.64	2.21	2.9	1	2.0
Calcium	(mg/l)	145.00	21.00	63.60	26.42	478	461	469.5
Magnesium	(mg/l)	33.00	2.40	9.64	6.38	41	15	28.0
Hardness	(mg/l)	498.00	62.30	198.38	94.29	1360	1210	1285.0
Alkalinity	(mg/l)	270.00	33.00	169.60	74.21	120	81	100.5
Sulfate	(mg/l)	39.00	2.00	14.23	9.29	1320	1190	1255.0
Chloride	(mg/l)	250.00	1.80	40.63	61.54	15	7.8	11.4
Silicate	(mg/l)	12.00	2.10	7.77	2.17	14	9.6	11.8
O-Phosphorus	(mg/l)	0.02	0.00	0.01	0.01	<0.01		
NO2+NO3	(mg/l)	7.40	0.00	0.67	1.48	<0.05		
Ammonia	(mg/l)	0.26	0.00	0.02	0.06	0.1	0.07	0.1
Iron	(mg/l)	1.60	<0.02	0.21	0.30	0.93	0.43	0.7
Manganese	(mg/l)	1.60	<0.01	0.09	0.29	0.91	0.75	0.8
Copper	(mg/l)	0.39	<0.01	0.10	0.09	0.06	<0.01	
Zinc	(mg/l)	4.30	<0.01	0.34	0.78	0.36	0.08	0.2
Color	(TCU)	110.00	<3.0	8.07	20.18	<3.0		
Turbidity	(NTU)	53.00	0.30	4.32	9.56	13	4.5	8.8
Conductance	(uS)	1430.00	180.00	512.63	274.73	3480	3100	3290.0
pH	(units)	8.80	6.70	7.74	0.42	8.2	7.8	8.0
TOC	(mg/l)	4.50	<0.50	2.30	1.11	2.2	<0.5	
Ion Sum	(mg/l)	679.00	93.60	259.08	127.00	1990	1750	1870.0
Langelier Index	(5 deg. C)	1.00	-0.70	0.13	0.30	1	0.4	0.7
Total Coliform	(Ct/100ml)	80.00	0.00	17.73	22.97	0		0.0
Fecal Coliform	(Ct/100ml)	52.00	0.00	2.07	9.39	0		0.0

Limited. A total of two drilled wells completed in gypsum bedrock, two rain water cisterns and 32 dug wells in silty glacial till were identified. Table 11 summarizes the well construction details and water quality results from this survey.

In general, the shallow surficial aquifer quality is a hard, alkaline, calcium bicarbonate to sodium chloride type, considerably different from the mine waters. Most of these wells are located outside the influence of mine dewatering.

3.3.4 Summary

In summary, the deep monitor wells exhibit a wide range of chemistry indicative of aquifer source, and degree of well development. Table 8 and Figure 8b illustrate major ion chemistry distribution for the deep wells, and the average domestic well and environmental monitoring well chemistry. A clear distinction is seen between the deep wells and the shallow domestic and environmental monitoring wells. Most of the deep wells are classified as calcium sulfate groundwaters, falling within a small area on the ternary diagram (Figure 8b). Based on the chemistry (Table 8), strong gypsum water signatures are seen at DW-2, DW-3 and ETW-1; evidence of surface water recharge (stratification) is observed at ETW-4 at Taylors pond, and DW-1 near the 107 area; and mixing between the calcium sulfate deep water and shallow calcium bicarbonate water is seen at in H-5, OW-3, and ETW-3.

Based on the background well chemistry, there is a vertical stratification of chemical signatures. The shallowest wells, represented by the domestic water quality results, are typically a strong calcium bicarbonate water with high hardness. The deep bedrock wells and mine waters are typically a strong calcium-sulfate water type. The trench waters overlying the mine are generally a mixture of deep sulfate waters and shallow bicarbonate waters, dominated by calcium and sulfate. TDS, sulfate, major ions and hardness generally increase with depth. Alkalinity, and pH generally increase with depth in the overburden, then decrease in the bedrock.

3.4 Surface Water Sampling

A total of 20 surface water sites were sampled to determine the chemistry of the Gays River water up-gradient, at various sites on the property and down gradient of the mine site, the tailings pond, sand quarry, and at twelve sinkhole sites. The sites (Table 12 and shown on Drawing 7170-1) were selected to provide a good representation of the range and variability of surface water chemistry within the possible hydraulic influence of the mine site.

Field monitoring of surface water stations at the 12 sinkhole locations along Gays River showed small ranges in the parameters measured: temperature averaged 20.3 degrees C, dissolved oxygen was near equilibrium with the atmosphere at an average of 7.7 ppm; electrical conductance was high due to mine water influence and baseflow conditions, at 2652 uS; pH averaged 7.8, increasing slightly in the down-stream direction, and uncorrected redox potential was in the order of 320 millivolts (Table 14).

3.4.1 Major Ion Chemistry

Figure 8c and Table 13 illustrate the distribution of major ion chemistry for surface water samples. The Gays River water is dominated by calcium and sulfate derived from gypsum deposits located throughout the watershed. The various samples exhibit very similar ionic proportions, falling within a small zone similar to Gays River mine water.

The up-stream samples (B1 and B11) exhibit the lowest TDS (< 700 mg/L), pH, alkalinity and a negative Langlier calcite saturation index, and represent river water entering the site. The main branch is less dominated by sulfate than the South Branch, which drains more karst terrain. Site discharges from the tailings pond (4000 USgpm) dominate the river water down-stream of the confluence with Gays River, resulting in increasing concentrations of hardness, TDS, pH, and SO_4, at the down-stream stations B3 and B14. This is also supported by isotope data (Section 3.6).

TABLE 12 SUMMARY OF ABOVE GROUND SAMPLE LOCATIONS AND DESCRIPTIONS

Sample ID	Type*	Hydro Lab Analyses	Description	Northing	Easting
B1	S	N	Gays River East Upstream	N 4,987,950	E 397,850
B3	S	N	S. Br. & Gays R. downstream	N 4,988,500	E 394,550
B7	D	N	Compliance Station "A"	N 4,988,050	E 396,650
B8	S	N	Compliance Station WCI-GR1	N 4,986,550	E 396,400
B10	B	Y	Centre of Tailings Pond	N 4,986,650	E 396,900
B11	B	N	S. Br. Gays R.	N 4,986,300	E 395,050
B13	B	N	Sand Pit Settling Pond	N 4,988,500	E 395,900
B14	S	N	Gays River East at Hwy. 277 Bridge	N 4,988,500	E 395,200
SH-1	P	Y	Sink Hole	N 4,988,750	E 396,190
SH-2	P	Y	Sink Hole	N 4,988,750	E 395,850
SH-3	P	Y	Sink Hole	N 4,988,750	E 395,800
SH-4	P	Y	Sink Hole	N 4,988,900	E 395,700
SH-5	P	Y	Sink Hole	N 4,988,750	E 395,350
SH-6	P	Y	Sink Hole	N 4,988,850	E 396,650
SH-7	P	Y	Sink Hole	N 4,987,600	E 397,050
SH-8	P	Y	Sink Hole	N 4,988,850	E 395,850
SH-9	P	Y	Sink Hole	N 4,988,870	E 395,750
SH-10	P	Y	Sink Hole	N 4,988,850	E 395,450
SH-11	P	Y	Sink Hole	N 4,987,800	E 397,150
SH-12	P	Y	Sink Hole	N 4,988,150	E 394,800

Note: S - Stream or River
B - Settling Pond
D - Drainage Ditch
P - Sinkhole Profile

TABLE 13 SUMMARY OF WATER CHEMISTRY DATA FOR SURFACE WATER SAMPLES
WESTMINER GAYS RIVER MINE - JUNE 24 to 27, 1991

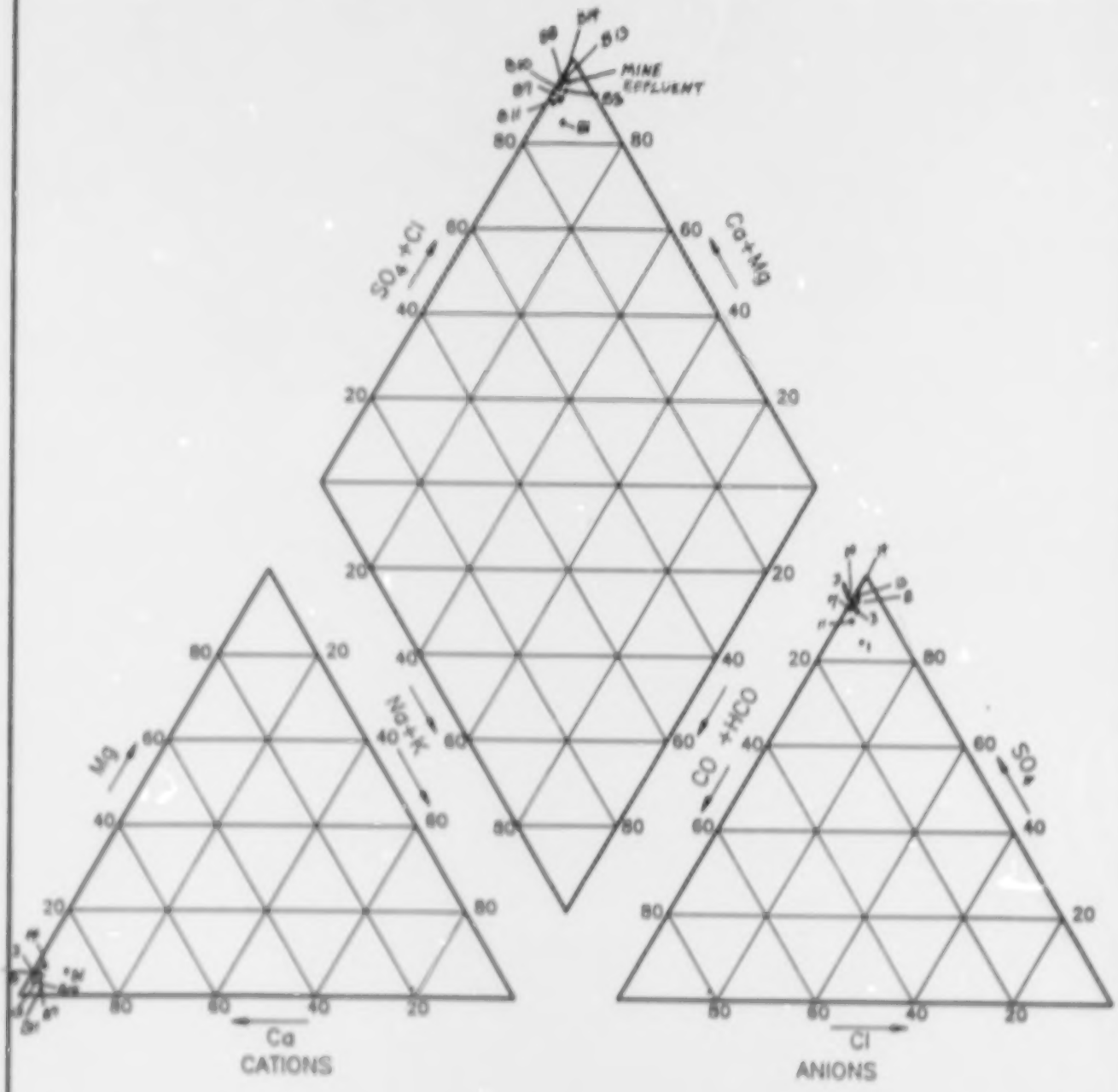
SAMPLE LOCATION		UNITS	B-1 Gays Riv Main Br. Upstream	B-3 Gays Riv 277 bridge Downstream	B-7 Stn. "A"	B-8 WCI-GR1 Tailings Outfall	B-10 Tailings Pond Centre	B-11 Gays Riv South Br. Upstream	B-15 Sand Quarry Seep	B-16 Gays Riv Main Br. Downstream
Sodium	(Na)	(mg/L)	6.1	9.8	9.3	10	10.1	4.6	9.8	11.4
Potassium	(K)	(mg/L)	0.4	1.2	0.8	1.4	1.1	0.8	0.9	2
Calcium	(Ca)	(mg/L)	78.1	337	318	399	441	190.00	366	461
Magnesium	(Mg)	(mg/L)	3.6	11.7	11.5	13.6	13.9	6.30	12.5	19.9
Alkalinity		(mg/L)	23	50	51	55	56	38	43	61
Sulphate	(SO4)	(mg/L)	191	869	823	998	1080	455	896	1160
Chloride	(Cl)	(mg/L)	8.9	12	12	12	12	4.4	12	14
Reactive Silica	(SiO4)	(mg/L)	0.8	<0.5	<0.5	1.6	3.3	2.3	<0.05	4.7
O-Phosphate	(PO4)	(mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	(NO3)	(mg/L)	<0.05	0.24	<0.05	0.38	0.3	<0.05	<0.05	0.39
Ammonia-N	(NH4)	(mg/L)	<0.05	0.12	<0.05	<0.05	<0.05	0.06	<0.05	<0.05
Color		(TCU)	13	5	9	5	4	11	8	4
Turbidity		(NTU)	1.03	1.67	0.72	0.85	1.31	1.32	0.62	>1000
Conductance		(umhos/cm)	520	2160	2060	2720	2940	1160	2370	3130
pH		(units)	7.1	7.4	7.6	7.6	7.8	7.2	7.3	7.2
Total Organic Carbon		(mg/L)	2.3	1.5	1.3	1	1.3	2.3	1.5	1.3
Hardness		(mg/L)	210	890	841	1050	1160	500	965	1230
Bicarbonate (as CaCO3)		(mg/L)	23	49.9	50.8	54.8	55.6	37.9	42.9	60.9
Carbonate (as CaC (HCO3)		(mg/L)	0.03	0.12	0.19	0.2	0.33	0.06	0.13	0.09
Ion Sum		(mg/L)	303	1270	1210	1460	1600	686	1320	1710
Langlier Index (5C)			-1.50	-0.30	-0.11	0.01	0.26	-0.83	-0.23	-0.29
Aluminum	(Al)	(ug/L)	22	35			17			
Antimony	(Sb)	(ug/L)	<2	<2			<2			
Arsenic	(As)	(ug/L)	<2	2			6			
Barium	(Ba)	(ug/L)	26	37			31			
Beryllium	(Be)	(ug/L)	<5	<5			<5			

Note: Iron(t) = total iron, unfiltered
Note: All metals field filtered 0.45 micron size, lab preserved with H2SO4.

TABLE 13 SUMMARY OF WATER CHEMISTRY DATA FOR SURFACE WATER SAMPLES
WESTMINER GAYS RIVER MINE - JUNE 24 to 27, 1991

SAMPLE LOCATION		UNITS	B-1 Gays Riv Main Br. Upstream	B-3 Gays Riv Z77 bridge Downstream	B-7 Stn. "A"	B-8 WCI-GR1 Tailings Outfall	B-10 Tailings Pond Centre	B-11 Gays Riv South Br. Upstream	B-13 Sand Quarry Sump	B-14 Gays Riv Main Br. Downstream
Boron	(B)	(ug/L)	9	26			39			
Cadmium	(Cd)	(ug/L)	<0.5	0.6			1.7			
Chromium	(Cr)	(ug/L)	<2	<2			2			
Cobalt	(Co)	(ug/L)	<1	1			1			
Copper(t)	(Cu)	(ug/L)	<10	<10	<10	20	20	<10	<10	60
Copper	(Cu)	(ug/L)	<2	5			10			
Iron(t)	(Fe)	(ug/L)	90	80	20	30	20	110	50	5100
Iron	(Fe)	(ug/L)	43	<10			<10			
Lead	(Pb)	(ug/L)	0.8	2.4			6.2			
Manganese(t)	(Mn)	(ug/L)	30	20	<10	<10	40	60	<10	1570
Manganese	(Mn)	(ug/L)	110	17			35			
Molybdenum	(Mo)	(ug/L)	<2	2			3			
Nickel	(Ni)	(ug/L)	5	17			27			
Selenium	(Se)	(ug/L)	<2	<2			<2			
Silver	(Ag)	(ug/L)	<0.5	<0.5			<0.5			
Strontium	(Sr)	(ug/L)	580	1500			2100			
Thallium	(Th)	(ug/L)	<0.1	<0.1			0.1			
Tin	(Sn)	(ug/L)	<2	<2			<2			
Uranium	(U)	(ug/L)	0.2	0.8			1.8			
Vanadium	(V)	(ug/L)	<2	<2			<2			
Zinc(t)	(Zn)	(ug/L)	<10	40	60	90	130	<10	30	1390
Zinc	(Zn)	(ug/L)	8	35			120			

Note: Iron(t) = total iron, unfiltered
Note: All metals field filtered 0.45 micron size, lab preserved with H2SO4.



GAYS RIVER HYDROCHEMICAL ASSESSMENT
DISTRIBUTION OF MAJOR ION CHEMISTRY

SURFACE WATER SAMPLES

FIGURE 8c

Westminer has reported that recent flow measurements along the Gays River main branch have indicated a flow of 2000 USgpm entering the site, and about 6000 USgpm downstream of the tailings pond outfall. This suggests that about 65% of the river water is mine effluent; this is supported by the observed river water chemistry. The major ion distribution of the 118 sump water, tailings pond water and downstream river water are similar.

In comparison to the mine waters, the stream water samples (B1, B3, B11, and B14) are lower in alkalinity (33% of mine water), 10 times lower in nitrate and ammonia concentration, slightly lower in pH (mean 7.2 vs. 7.6 for mine water), exhibits approximately 50% of mine water TDS and dissolved ions, higher TOC, higher magnesium, and lower trace metals such as boron and strontium. These parameters may be useful in assessing river water components of mine flow.

3.4.2 Metals Distribution

Field filtered metals analyses were performed for three stream water samples. B-10 represents metals concentrations in the tailings pond, and can be used for comparison of metals both up-stream (B-1) and down-stream (B-3) of the outfall. The metals concentrations of Gays River water entering the area are very low, and all parameters except manganese (0.11 mg/L) fall within Canadian Drinking Water Guidelines (1989). In order of concentration, the most common elements include strontium, manganese, iron, barium and aluminum. Concentrations of most trace elements increase in the down-stream direction, and correlate well with the tailings pond waters.

3.4.3 Tailings Basin

Sample B10 was collected from the centre of the tailings basin at a depth of 3 m below surface. This water is almost identical in major ion composition to the 118

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drainhole samples (Figure 8a). The hydrolab profile (Table 14) indicates a 4.2°C decrease in temperature, increasing conductance, and chemical stratification in the water column. Dissolved oxygen was greatest in the middle portion (1.6 m) and was over saturated possibly due to wave turbulence over the previous few days. A dramatic decrease in pH from 8.5 to 7.5 was noted in the deepest samples. This may be a consequence of concentrator effluent or presence of sulfides at depth. Redox potential was also greatest at the bottom. The highest surface water pH (8.53) was in the tailings pond. The remaining samples averaged 7.8 units.

Sample B8 was collected at the compliance monitoring station WCI-GR1 in the week of June 17 to 21. This sample is similar to the tailings pond sample B10, and correlates with the compliance monitoring results for June 17 to 24, 1991.

3.4.4 Summary

Because the surface water is dominated by the mine discharge water at this time of year, it is difficult to see clear correlations between individual boreholes and surface water sources. Monitoring of key indicator parameters such as Temperature, D.O., conductance, etc. over several months may provide a clearer picture.

Increases in aluminum, lead, arsenic, strontium and other elements downstream of the tailings pond outfall may be useful in calculating the proportion of mine water discharge to stream flow; these results indicate that it is significant during the dry period.

3.5 Sink Hole Profiling

The Hydrolab was used to profile the twelve known sinkholes which are located in Gays River north of the mine site (Table 14). Readings at each sinkhole were taken at the surface, middle and bottom in order to determine any changes in the chemistry with depth

which might indicate an active sinkhole. The Hydrolab was also used at site B10 (Tailings Pond) to record in situ chemical data. The sampling sites and sink-hole locations are illustrated on Drawing 7170-1.

3.5.1 Previous Investigations

Sinkholes in Nova Scotia form in terrain underlain by soluble bedrock such as gypsum. Infiltrating rainwater and shallow aquifer water which is under-saturated with respect to gypsum, (in the Gays River case), causes enlargement of cracks and fissures into solution pipes and caverns. Over time, these voids become filled with sediment from above, or tend to collapse when hydrostatic pressure is reduced by drainage.

Drawing 7170-1 illustrates the distribution of some of the sinkholes in the vicinity of the trench and mine areas. Numerous sinkholes are reported in glacial deposits overlying the 119 area. There has been a concern over possible massive river water infiltration through sinkholes in the Gays River floodplain since the mine opened. Sinkholes on the land surface in the vicinity of the 104 and 119 mine areas were first documented during the IOL mining operations in the 1970's. McKee & Hannon (1982) noted a correlation between seasonal precipitation events, river flooding, and pumping rates and sediment loads at the 118 and 119 sumps. Sinkhole activity resumed in the 119 area during the initial Westminer dewatering operations, resulting in at least two major sinkholes on land in the vicinity of the trench. These were filled, and capped with clay to limit infiltration (Meyer, 1991).

Five to seven possible sinkholes were identified in the bed of Gays River by Martec (1981) during pre-closure surveys. The river in these areas is about 1.3 to 1.5 m deep, and 2 to 3 m wide. It is not known whether these original holes were a result of mining activity, however, it is suspected that most pre-dated mining since the river course follows the sinkhole depressions. Follow-up surveys in 1988, 1989, 1990 and 1991 (Martec 1988, 1989a, b, 1990a, b, 1991) indicated up to 12 sinkholes along the

river between the Newman's Bridge and the confluence of the main and South branches of Gays River. Some holes varied in size due to stream sediment movement; some holes appeared to be getting larger in the most recent surveys (Holes 8, 10a, 10b, Martec 1990a,b).

Recent hydrometric surveys of Gays River have identified a water balance discrepancy in the vicinity of Sinkholes #6 to #5. A stream flow survey in June 18-19, 1991 (Martec 1991) indicated a net stream loss of up to 34% between Sinkhole 6 and Sinkhole 5. This loss of 7824 l/min (2067 USgpm) occurs along a stretch of river containing up to 9 sinkholes (Drawing 7170-1), at a low flow period. A similar survey by Martec on November 8, 1989 some 8 months after mine dewatering operations commenced indicated an approximate 50% increase in river flow along this stretch. The extreme difference (e.g. 50% gain in Nov. 1989 and 34% loss in June 1991) may be due to seasonal effects (fall recharge event with high component of runoff, compared to low flow drought conditions experienced in June 1991), or the fact that the cone of drawdown due to mine dewatering was likely less in 1989 than it is at present.

A recent survey by Adrian Brown has indicated an approximate 4000 USgpm (15,000 litre/min) drop in flow between Sinkhole #1 and the bridge at sinkhole #5. A follow-up survey by Martec (July 1991) also showed a drop in flow in the order of 1200 USgpm (5500 litres/min) over the same interval. Although the discrepancy in volume is presently unresolved, a loss of river water is definitely indicated over the mine trench area.

Dye testing of Gays River by Martec Limited in February of 1991 suggested that less than 1% leakage is occurring; this is inconsistent with recent investigations.

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3.5.2 Sinkhole Distribution

Drawing 7170-1 and Figure 10 illustrate the distribution of sinkholes on land and on the bottom of Gays River (after Martec, 1989, 90, 91). It can be seen that numerous sinkholes occur in glacial deposits directly above the trench, including Taylors's pond located north of Gays River, and River sinkholes #'s 6, 1, 2 and 3. Several sinkholes (4, 8, 9) are located near the 119 mine areas.

3.5.3 1991 Hydrochemical Profiling

The Hydrolab unit was used to profile Sinkholes 1 through 12 during the week of June 17 to 21, 1991. The sensors were lowered slowly through the water column, and measurements of temperature, dissolved oxygen, conductance, pH and Eh were made at the surface (0.1m depth), middle and near bottom of the sinkhole. The objective was to determine if thermal or chemical stratification is present (indicating non-active sinkholes) or if continuous chemistry exists from water surface to bottom of sinkhole (indicative of an influent situation).

Table 14 presents the results of sinkhole profiling. The bottom of the sinkholes averaged 3.3 m below the water surface, and the stream averaged 1.2 m in depth. The temperature of the surface averaged 20.7 degrees Celsius with an average temperature difference of 0.52 degrees from surface to bottom. Dissolved oxygen at the water-air interface is near saturation with respect to oxygen, averaging 8 ppm, and generally decreases with depth below the water surface, ranging 0 to 1.0 ppm, and averaging 0.4 ppm from top to bottom. The pH averages 7.5, and generally decreases by 0.14 pH units from surface to bottom. There was little variation in conductance or redox potential in these shallow profiles.

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TABLE 14. IN-SITU CHEMICAL MONITORING OF SURFACE WATER SITES AND SINKHOLE PROFILES - WESTMINER GAYS RIVER MINE

SITE LOCATION	SAMPLE DEPTH (m)	TEMP (C)	DISSOLVED OXYGEN (ppm)	DISSOLVED OXYGEN (% sat.)	TDS (mg/L)	CONDUCTANCE (uS)	FIELD pH	pH (Lab)
SINKHOLE-1	0.1	20.52	8.00	98.0	1744	2492	7.73	317
SINKHOLE-1	1.72	19.53	7.17	84.6	1751	2501	7.59	319
SINKHOLE-1	3.43	19.38	7.02	83.9	1748	2497	7.56	318
SINKHOLE-2	0.1	20.21	7.89	96.0	1746	2495	7.71	329
SINKHOLE-2	1.45	19.47	7.29	86.9	1740	2486	7.63	332
SINKHOLE-2	3.33	19.33	7.21	85.7	1743	2489	7.60	333
SINKHOLE-3	0.1	20.22	7.80	94.0	1751	2501	7.70	334
SINKHOLE-3	2.9	19.59	7.24	86.9	1744	2492	7.62	336
SINKHOLE-3	3.81	19.42	7.14	85.1	1743	2489	7.60	338
SINKHOLE-4	0.1	20.32	7.79	94.3	1756	2508	7.74	337
SINKHOLE-4	1.5	20.37	7.77	93.7	1738	2480	7.74	338
SINKHOLE-4	3.0	20.32	7.77	94.1	1747	2495	7.73	339
SINKHOLE-5	0.1	22.40	7.15	90.8	1749	2499	7.68	315
SINKHOLE-5	1.7	22.24	7.77	98.1	1745	2493	7.68	313
SINKHOLE-5	3.5	22.09	7.66	99.1	1765	2521	7.85	308
SINKHOLE-6	0.1	21.06	7.92	97.7	1733	2476	7.76	307
SINKHOLE-6	1.75	19.92	7.09	85.5	1756	2509	7.61	309
SINKHOLE-6	3.5	19.90	6.74	81.3	1744	2491	7.55	309
SINKHOLE-7	0.1	20.17	8.04	97.8	1781	2544	7.84	308
SINKHOLE-7	1.8	19.88	8.11	98.4	1783	2547	7.85	306
SINKHOLE-7	3.6	19.49	7.82	93.2	1767	2524	7.78	305
SINKHOLE-8	0.1	20.05	7.54	91.6	1753	2504	7.68	338
SINKHOLE-8	1.22	20.02	7.56	91.4	1750	2500	7.68	340
SINKHOLE-8	2.43	19.99	7.66	92.1	1749	2498	7.68	342
SINKHOLE-9	0.1	20.35	7.64	93.5	1750	2500	7.71	338
SINKHOLE-9	0.92	20.15	7.63	93.1	1749	2498	7.70	340
SINKHOLE-9	1.83	20.13	7.57	93.6	1757	2510	7.70	341
SINKHOLE-10	0.1	20.88	7.99	98.3	1738	2482	7.80	316
SINKHOLE-10	2.17	20.02	7.29	88.4	1736	2480	7.68	318
SINKHOLE-10	4.28	19.95	7.04	85.0	1743	2491	7.64	317
SINKHOLE-11	0.1	20.48	8.06	97.8	1763	2519	7.84	304
SINKHOLE-11	1.2	20.42	8.14	99.5	1767	2525	7.85	302
SINKHOLE-11	2.3	20.40	8.11	99.2	1761	2516	7.84	301
SINKHOLE-12	0.1	22.19	7.55	92.5	1736	2479	7.94	309
SINKHOLE-12	0.8	22.19	7.5	88.8	1735	2478	7.94	306
SINKHOLE-12	1.7	22.19	7.36	85.4	1741	2487	7.94	302
Tailings Pond	0.1	21.02	9.25	116.3	2077	2968	8.52	354
Tailings Pond	1.6	19.89	10.35	130.1	2092	2988	8.53	361
Tailings Pond	3.2	15.8	7.77	88.5	2135	3049	7.5	331

3.5.4 Summary

Based on similar temperature, dissolved oxygen concentration and pH, three sinkholes appear to be recharging the river bottom, namely #4, #8 and #11. Sinkhole #5 may also be active, however mixing may have occurred due to swimmers at the time of profiling. Sinkhole #12 is uncertain due to the shallow depth (1.8 m).

This activity provides more insight into the inferred loss of stream flow in certain locations with respect to potential river recharge through sinkholes. Sinkholes 4 and 8 are in the stretch of river shown to lose 34% of flow (about 7.6 m3/min or 2000 USgpm). Further investigation of these areas is warranted.

3.6 Isotope Analysis

3.6.1 Introduction

Water samples from selected sampling sites were subjected to environmental isotope analysis at the Environmental Isotope Research Lab, University of Waterloo, Ontario. Based on the results of the inorganic chemistry analysis, a total of 20 sites representative of the various flow rates and chemical water types throughout the mine were analyzed for oxygen-18 and tritium. Based on the distribution of the oxygen-18 results, six samples were then analyzed for deuterium to allow comparison of mine waters with local meteoric waters. Seven samples were analyzed for sulfur-34, and two rock samples, one from the gypsum and one from the sulfide ore, were analyzed to determine the source of the dissolved sulfate. Isotope results are presented in Table 15.

TABLE 15 SUMMARY OF ISOTOPE CHEMISTRY RESULTS - WESTMINER GAYS RIVER MINE June 1991

SAMPLE LOCATION		FLOW RATE (L/min)	OXYGEN-18 (o/oo)	(*)	DEUTERIUM (o/oo)	TRITIUM (TU)	SULFUR-34 (o/oo)	SULFUR - (o/oo)
606	Drain Hole (PT-3)	1000+	-8.37	-8.36	-49.65	15.0		
			-8.34		-49.85			
603	Borehole (PT-6)		-8.85	-8.85		9.0	12.36	11.02
PT-2	Borehole 620, West	19	-8.36	-8.34		13.0		
			-8.32					
W-2	Borehole, West	5	-9.07	-9.07		14.0		
PT-5	Borehole 641		<8.73	-8.73		<8.0		
656	656E Drain Hole	25	-8.74	-8.73		9.0		
			-8.71					
214	Drain Hole, east end	est 15	<8.76	-8.74	-52.63	<8.0		
			-8.71					
PT-9	Borehole, 201 drift	12	-8.86	-8.81		10.0	15.68	9.93
			-8.76					
118-1	118 sump drain hole No.1	4000	-8.55	-8.58	-50.15	20.0		
			-8.27					
118-2	118 sump drain hole No.2	4500	-8.17	-8.14		7.0	15.40	10.89
			-8.11					10.19
118-F	118 water inrush area		-8.75	-8.73	-51.69	19.0	15.15	10.71
			-8.70			28.0	14.58	
FT-8	119 Clean-out		-8.47	-8.56		13.0		
			-8.64					
W-4	Borehole, 201 drift	seepage	-8.52	-8.50		17.0		
			-8.47					
101	Borehole, 101-2 drift	600+	-8.90	-8.87		<8.0		
			-8.83					
PT-7	101-D drift		-8.68	-8.76		11.0	13.72	11.45
			-8.84					
R-1	Roof seepage, 106 ramp	seepage	-9.07	-9.06	-50.02	9.0		
			-9.04					
OW-3	Observation Well in Trench		-8.27	-8.43		6.0		
			-8.58			10.0		
B-1G	Tailings Pond		-7.66	-7.75		10.0		
			-7.85					
B-1	Gays River Up-stream		-8.60	-8.61	-41.96	7.0	14.02	11.22
			-8.62		-43.54			
B-3	Gays River Downstream		-7.49	-7.52		9.0	12.73	11.60
			-7.55					11.32
116 + 107	Gypsum Rock Sample						14.31	
							14.22	
206R	Sulfide Rock Sample						5.76	
							5.66	

* Average of duplicate analysis o/oo parts per thousand (per mil) TU - Tritium Units

1. Analysis by Waterloo Environmental Isotope Lab, Waterloo Ontario.

3.6.2 Environmental Isotopes - Definition of Terms

The stable isotopes of oxygen (O-16 and O-18), and hydrogen (hydrogen, deuterium and tritium) are naturally occurring in normal precipitation and combine to form water molecules at the following relative abundances:

Isotope	Formula	Weight %
Hydrogen	$^{1}H_{2}$	99.9984 %
Deuterium	$^{2}H_{2}$	0.0156 %
Tritium	$^{3}H_{2}$	10^{-4} % to 10^{-6} % (radioactive)
Oxygen-16	$^{16}O_{x}$	99.763 %
Oxygen-18	$^{18}O_{x}$	0.1995 %

These isotopic ratios are established when the water molecule forms as it condenses as rain. Empirically, the isotopic concentration of groundwater is similar to that of the average isotopic composition of precipitation as a whole. Since deuterium and tritium are isotopically conservative or non-reactive elements, the water recharged into the ground retains its isotopic signature over long distances of transport and long time periods. Variations in concentrations may indicate dilution with other waters encountered along the way, or chemical change in the case of oxygen-18.

Tritium (^{3}H) is a naturally-occurring radioactive isotope of hydrogen with a half life of 12.26 years (e.g. one half of the tritium atoms will disintegrate every 12.26 years). Tritium is formed in the upper atmosphere by cosmic ray reactions, producing a "natural" background concentration of 5 to 10 TU, and by man-made nuclear activities. Tritium concentration is generally reported as tritium units (TU), where one tritium unit is defined as one tritium atom for 10^{18} hydrogen (1H) atoms, or 2.3 picocuries per litre radioactivity, and is measured by liquid scintillation counting of raw (detection limit 6 TU) or distilled samples (detection limit 0.8 TU).

During the 1950's and 1960's, atmospheric thermonuclear testing resulted in atmospheric tritium levels reaching more than 1000 TU at the Ottawa monitoring station (Figure 11a), followed by a steady decline after 1970 since atmospheric testing was banned. The present atmospheric concentration is 39.0 TU in the Ottawa area, and 10 to 12 TU in Atlantic Canada (B. Drimmie, pers. comm., Waterloo Isotope Lab). This man-made tritium input is useful as a direct groundwater dating tool. In general, tritium concentrations of zero to 1 TU are indicative of groundwater recharged more than 35 years ago (e.g. pre-bomb era), concentrations of 1 to 12 TU indicate groundwater recharged within the past 35 years, waters with 50 to 100 TU were likely recharged between 1960 and 1965 during the height of the atmospheric testing, and significantly higher levels of tritium may be due to the presence of radioactivity or analytical error.

Oxygen-18 and Deuterium

Both isotopes are an integral part of any water molecule. Relative concentrations of oxygen-18 (^{18}O) or deuterium (^{2}H) are compared to a standard called Standard Mean Ocean Water (SMOW), and reported as parts per thousand (permil or o/oo) difference from this reference. For example, an Oxygen-18 value of -10 o/oo indicates that the water sample has 10 parts per thousand less Oxygen-18 than the standard, and is said to be "depleted in the heavy isotope Oxygen-18".

Mean ocean water typically has near zero deuterium and oxygen-18. During the evaporation process, the lighter isotopes are preferably taken up into the air, which is depleted in deuterium and oxygen-18 relative to sea water by 80% and 9% respectively (Dansgaard, 1964). As the air mass moves, the heavier isotopes are lost first during condensation further depleting the heavy isotope composition of the air mass. As air vapour is carried from the ocean to the land, it becomes progressively more depleted in these heavy isotopes in comparison to ocean water. Depletion increases with distance from the sea, latitude, elevation and temperature. Many

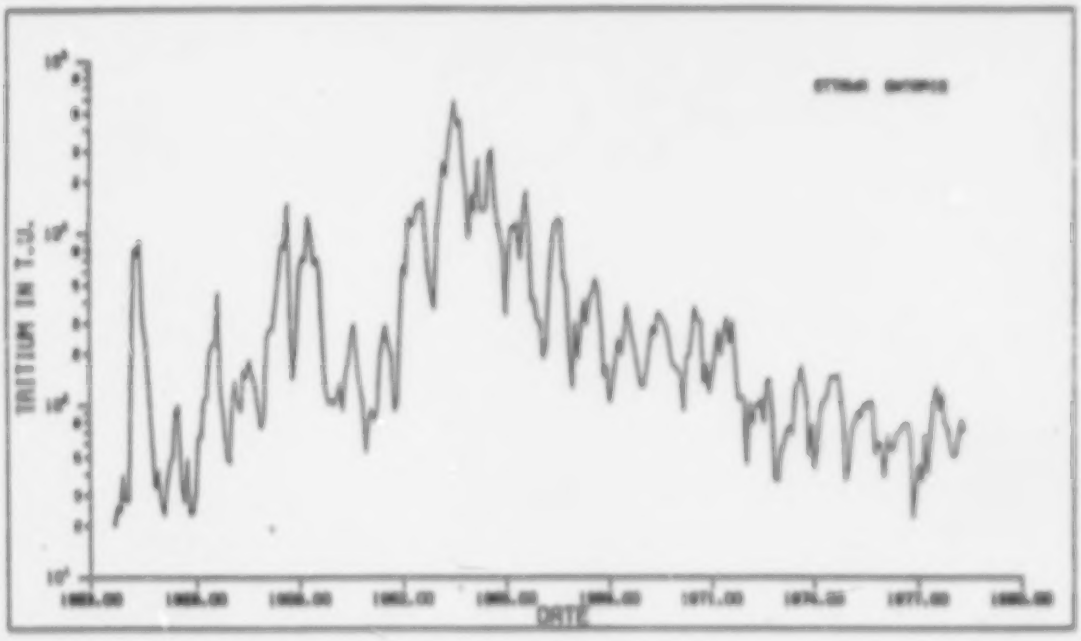

FIGURE 11a. AVERAGE MONTHLY TRITIUM CONCENTRATION IN RAINFALL AT OTTAWA, ONTARIO. (1953 TO 1978).

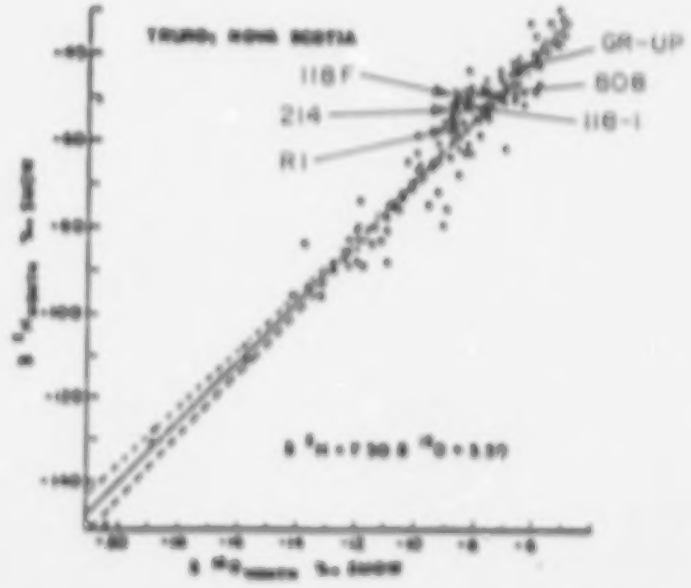

FIGURE 11b. AVERAGE MONTHLY OXYGEN-18 AND DEUTERIUM (DEL SMOW) FOR TRURO METEOROLOGICAL STATION. (FRITZ, DRIMMIE, FRAPE, G'SHEA, 1986).

concentrations of heavy isotopes are lower in rainwater in cooler climates than in warm climates.

Sulfur Isotopes

Sulfur 34 and Oxygen-18 in sulfate can be employed to understand the origin and geochemical history of sulfur in groundwater, and in geological/stratigraphic studies involving dewatering of evaporite deposits. Sulfur has two major naturally occurring isotopes: S-32 (95.02 %) and S-34 (4.21 %). Concentrations are expressed in "permil" (o/oo) differences from the Canyon Diablo Meteorite standard. Oxygen-18 abundances are expressed in o/oo relative to SMOW, as discussed above. The S-34 ratio provides an indication of the origin of the sulfate, while the O-18 provides an indication of the geochemical history of the sulfate in the water (e.g. gypsum dissoiution).

3.6.3 Discussion of Results

The isotopic signatures for the selected sampling sites exhibit a reasonable range of values, which may be used to characterize the various water sources as follows:

	Trench/ Gypsum Contact	Trench/ Carbonate Contact	Gays River Upstream	Mining Tailings/ Downstream
^{3}H	11.0 - 28.0	<6.0 - 10.0	7.0	9.0 -10.0
Oxygen-18	-7.8 to -8.4	-8.4 to -8.7	-6.2	-7.1 to -7.4
^{2}H	-49.6 to -51.7	-52.6 to -55.5	-42.8	na
S^{34}	13.7 to 15.4	12.4 to 15.7	14.02	12.73

Oxygen-18 and Deuterium

The Oxygen-18 averages -8.05 for the 16 mine water samples, and -6.25 for the up-stream Gays River Sample, ranging between -7.8 at the 118 sump drain holes, to -8.71 o/oo for shallow mine water samples at W2 and R1. The deuterium averages -53.7 o/oo, ranging from -49.5 o/oo to -55.5 o/oo for the 5 mine water samples analysed, and -42.3 o/oo for Gays River upstream. In comparison to SMOW, the mine waters are depleted in heavy isotope concentration by about -60 o/oo for deuterium and -8.0 o/oo for Oxygen-18.

On a global basis, the ratio of deuterium and oxygen-18 plot on a straight line called the Global Meteoric Water Line (GMWL). The position of the point depends on latitude and climatic effects. This line generally has a slope of about 8.0, and a Y-intercept of around + 10 permil 0-18. Deviations from this line signal evaporation or chemical processes, and can be used to infer possible source (climate of recharge) and pathways.

A meteoric water line for Truro, located 30 km northeast of Gays River, is shown on Figure 11b. The six 2H - O18 couplets fall close to the Truro meteoric water line which is dominated by air masses originating in the Atlantic ocean or Gulf of Mexico (summer-fall) or arctic air masses in winter.

The samples are displaced slightly upward, indicating enrichment in deuterium. The deuterium excess concentration is in the order of 14 o/oo for deep mine water, and 7.5 o/oo for surface water (B1). For the Truro station, deuterium depletion averages 10.6 o/oo annually which is similar to the GMWL, with ranges of 4.1 to 13.8 in summer, and 9.1 to 15.6 in winter (Fritz et al, 1987). This suggests that the surface water is consistent with summer rain conditions, and the mine waters are reflecting groundwater mixing with waters recharged during the winter or mixing with older paleowaters.

Tritium

The presence of detectable tritium in the mine waters infers the presence of relatively young water (either surface water or groundwater) which entered the mines within the past 35 years.

The tritium concentration for 16 underground mine water averages 12.5 TU, compared to 8.7 TU for the three surface water samples (Table 15). Although the detection limit is 6 TU, some tritium at <6 TU may be present; enriched tritium analysis would be required to confirm this. For the purposes of this assessment, tritium concentrations in excess of 10 TU will be considered to be significant, and to indicate the presence of tritium derived from mixing with recharging meteoric waters, shallow groundwater or river water) in this mine; values between 6 and 10 TU may contain atmospheric tritium.

The highest tritium concentrations (> 10 TU) appear to occur along the trench-gypsum contact south and west of the mine. Lower concentrations occur along the trench-carbonate contact (<6 TU to 9 TU), and only 3 of the 16 underground sites exhibited non-detectable tritium (PT5, 101, and 214 in the east area, at the gypsum-carbonate contact).

The highest Tritium concentration (28 TU) noted at 118-F, an area of "old" or non-diluted gypsum water chemistry, likely reflects presence of bomb tritium recharged between 20 and 30 years ago.

The high flow boreholes (118 sump, 808) exhibit significant tritium concentrations indicative of groundwater less than 30 years in age, and more likely recharged over the past few months given the high flow rates. The tritium concentrations are similar to the present meteoric tritium concentrations. It is possible that these waters contain very recent meteoric waters. The slower flowing sites along the trench-carbonate

contact generally exhibit lower tritium, possibly indicative of older water, or mixing between older groundwater and shallow groundwater (R1).

The well water at OW-2 indicates old or stagnant groundwater with tritium concentrations < 6 TU.

Sulfur-34

This naturally-occurring sulfur isotope was analysed to assess the source of the sulfate waters in this mine and to determine the proportion of mine water in Gays River. Sulfur-34 ranged from + 12.4 to + 15.7 o/oo (mean + 14.5 o/oo) for the 5 mine water samples, and + 12.7 to + 14.0 o/oo for the stream samples. A sample of the gypsum bedrock indicated a S-34 value of + 14.25 o/oo, and a sulfide ore sample indicated + 9.7 o/oo S-34.

Based on the above, the source of the dissolved sulfur is the gypsum bedrock. Using the S-34 results for gypsum, the gypsum bedrock is Missippippian to Pennsylvannian in age (Krouse, 1980); this is the assumed age of the gypsum deposit in this area.

The oxygen-18 in the sulfate exhibits an average composition of + 10.71 o/oo compared to a mine water O-18 composition of -8.66 o/oo. This enrichment in heavy isotope is not meteoric in origin, rather it is due to evaporation during formation of the gypsum.

Conclusion

Although it is difficult to draw concise conclusions from one set of samples, the following trends are suggested from the isotope data:

The environmental isotope data indicates that the Gays River mine waters are dominated by meteoric waters recharged into the gypsum karst aquifer and trench areas over the past few years. The concentration and distribution of tritium, oxygen-18 and deuterium and observed flow rates suggests that a greater amount of surface source mixing occurs along the more permeable gypsum-trench contact than at the carbonate-trench contact. The sulfur isotopes indicate the source of the dissolved sulfate to be from gypsum dissolution.

The mine waters are isotopically different from the surface waters; the distribution of environmental isotope concentrations indicates a degree of mixing between the stream water and the groundwater entering the mine. For example, local rainwater and stream waters are less depleted in the heavier isotopes. Formation waters recharged during Pleistocene times would be expected to be more depleted in heavier isotopes.

The three samples collected at the tailings pond, and Gays River up-stream and down-stream (Table 15) illustrate the effects of mixing between the background stream waters entering the site (7.0 TU), the composite mine water (10 TU) and the downstream water (9.0 TU). This is supported by Oxygen-18 which decreases downstream, and sulfur-34 which is intermediate between the upstream value and the mine waters. This supports the inorganic chemistry data which suggests that mine water dominates the stream water downstream of the tailings outfall. This was confirmed when the outfall was diverted to the west outfall late in 1991.

Seasonal monitoring of environmental isotopes at selected stations (e.g. 118 and 808 areas) should provide more insight into the source of the mine water.

4.0 SUMMARY OF CONCLUSIONS

Based on the review of two years of mine water quality monitoring data, and one set of spatial hydrochemical data representative of the dry period of the year, the key conclusions derived from this hydrochemical investigation are as follows:

1. The primary source of mine water is derived from storage in the cavernous gypsum bedrock aquifer northwest of the mine complex. This water is intercepted by permeable deposits in solution cavities and the erosional trench, and conveyed to the mine at an approximate steady rate of 4000 USgpm.

2. This calcium-sulfate water is being mixed or "diluted" by other groundwater of lower TDS derived from other sources, such as the river floodplain, Meguma and Carbonate bedrock aquifers, trench fill deposits, overburden aquifers, and the sand quarry, or a combination of these.

3. The 1989 to 1991 mine water discharge chemistry data indicates a significant input of shallow groundwater and surface water during the wet portions of the year (spring and fall). The June 1991 spatial data representing a dry period also indicates significant mixing with shallow waters of meteoric origin in some areas of the mine.

4. The spatial underground chemistry and hydrolab results indicate four mine water chemical types, with four possible sources: (1) a weak calcium-sulfate water type with magnesium associated with mixing of shallow water and carbonate aquifer water along the southeastern carbonate-trench contact, (2) a strong calcium-sulfate type associated with the northwestern gypsum-trench contact, (3) a "diluted" calcium-sulfate type in the vicinity of the large drainholes at 118 and 808 which dominates the composite mine water chemistry, and (4) a zone of shallow more diluted calcium-sulfate groundwater in the portal-access ramp areas at R1, W4, and in the 858 area. Figure 10 illustrates the various chemical types identified.

Jacques Whitford Environment Limited	REFERENCE	SCALE: AS SHOWN DATE: 91/08/02 DRAWN BY: U.M.W./G.C. APPROVED BY:	WESTMINER CANADA LIMITED GAYS RIVER HYDROCHEMICAL ASSESSMENT GAYS RIVER, HALIFAX COUNTY, NOVA SCOTIA	DISTRIBUTION OF MAJOR WATER TYPES FOR UNDERGROUND SAMPLE LOCATIONS – JUNE 1991	DRAWING NO. FIGURE 10

5. The chemical, isotopic and flow monitoring information indicates that most of the mine water is associated with the trench-gypsum contact where a greater degree of fracturing, solution cavity formation and permeability may be expected. The gypsum in this area is likely in hydraulic connection with the overlying permeable overburden deposits identified in the north and west area. Only a minor component of flow is expected from the carbonate-trench contact where lower permeability, longer groundwater residence time and minimal solution cavity formation is expected.

6. In-situ monitoring, chemistry and isotopic data indicate a significant degree of mixing between gypsum formation waters and shallow meteoric waters at the major water drainholes at the 118 and 806 areas, and in the western portions of the mine complex.

7. The environmental isotope analysis indicates that the mine waters are dominated by water of meteoric origin. The deuterium and oxygen-18 analysis indicate waters of meteoric origin, possibly recharged in the previous winter, or mixing with waters recharged during the Pleistocene era. Tritium in all the major drainholes, and 13 of the 16 underground boreholes analysed for isotopes, indicates the mine water was recharged since 1965; the concentrations of tritium at the major drain holes suggests recent contact with waters of meteoric origin.

8. The primary recharge to the mine workings appears to originate from a northwest direction. The chemistry and isotope data suggest that the primary source of the low TDS mine water is from extensive sink hole development and permeable sands located along Grays River to the northwest of the 118 area. These conduits could allow river water to surcharge the gypsum and trench aquifers, resulting in the observed seasonal fluctuations in mine discharge rate. Several factors support this conclusion: (a) the sinkhole profiling results indicate up to 4 active sinkholes in this area; (b) several previously active sinkholes were plugged in this area; (c) recent stream measurements along this area show a 34% reduction in stream flow between sinkholes #6 and #12, for a loss of 2000 USgpm; (d) the mine water chemistry and

isotope data for the 118, 119 and 808 areas show a high probability of surface water recharge at the gypsum-trench contact from this direction; (e) recent diversion of the tailings water to the South Branch has demonstrated a significant reduction in stream flow along this area; (f) recent test drilling and monitor well installations along Gays River have identified significant deposits of permeable sand, with depressed water levels, and implied downward vertical hydraulic gradients; and (g) deep observation wells DW-1 and ETW-1 indicate diluted formation waters indicative of mixing with shallow waters.

9. The portal area in the vicinity of the sand quarry is being recharged from the overlying surficial deposits through the fractured bedrock enclosing the portal and ramps. The lack of water in the sand pit is due to the dewatering activity.

10. Analysis of the temporal mine water chemistry data indicates that the composite mine waters and waters from the major drain holes are undersaturated with respect to gypsum, indicative of actively dissolving gypsum. The Sulfur-34 isotopes indicate that the dissolved sulfate is derived from gypsum dissolution.

11. The best indicators of mine water mixing with water from a surface source are: presence of tritium (> 10 TU) or dissolved oxygen (> 1.0 ppm), elevated groundwater temperature (> 10 degrees C), high redox potentials, and chemical dilution effects (elevated concentrations of alkalinity, sodium and chloride, and lower than background concentrations of major ions (such as sulfate), TDS, and electrical conductance.

12. Hydrochemical profiling of 12 sinkholes in Gays River has identified three active sinkholes (#4, #8, #11), and possibly two others which may be active (#5, #12). Some of these are located in the vicinity of the 119 and 118 mine areas.

13. Both chemistry and isotope data show that the river water chemistry below the tailings pond discharge point is dominated by the mine discharge water, at least during the dry portions of the year. Preliminary mass-balance estimates suggest about 60% of the river water is derived from mine water in late June, 1991.

14. If it is assumed that the mine is in equilibrium with the gypsum aquifer most of the time, the main source of additional inflows during wet periods and river flooding stages appears to be from Gays River, through the associated permeable surficial aquifers and sinkhole conduits (possibly undetected below the sand aquifer), which may act as conduits between the floodplain and the bedrock/trench contact.

15. This investigation supports the likelihood of a significant river water component to the mine water flows with a seasonal variation in input.

5.0 RECOMMENDATIONS

A program of mine water quality monitoring is recommended to confirm the conclusions of this investigation. The following recommendations are presented for further investigation into the source of mine waters at Gays River.

5.1 Mine Water Monitoring Strategy

Based on the above review and assessment, the following monitoring strategy is recommended:

5.1.1 Recommended Sampling Locations

Based on the 'snapshot' sampling program of the Gays River Mine Complex, the following stations are recommended for on-going mine water monitoring:

A. Major Monitoring Sites (Class 1)

These are the major water flows and high flow drain holes currently under development. At a minimum, Class 1 sites would include sample sites at:

* mine discharge weir at pipe outfall
* One of the 118 sump drain holes (No.1 or No.2)
* new drain holes at 808 drift
* 858 drain area
* 863 drain area
* drain holes in the vicinity of 119 sump
* inflow at 118-F area

B. Secondary Monitoring Sites (Class 2)

These sites are intended to provide temporal monitoring of mine water chemistry.

* PT-series monitor holes
* 804
* 101
* 856
* a borehole in 214 drift
* W-1 in the Portal Area

These suggested locations should be revised using new monitoring points after completion of the current underground drilling program.

5.1.2 Monitoring Strategy

* One simple and inexpensive monitoring parameter is temperature. Monitoring of temperature at all underground and above ground monitoring stations should be performed on a monthly basis, and temperature of the major monitoring sites (118-1, 119A, 808, etc., WCI-GR1, mine discharge water) should be determined at least weekly. The mine water averages about 8.5 degrees Celsius. Higher temperatures in summer or lower temperatures in winter could indicate hydraulic connection with the surface.

* Electrical conductance should be monitored on the major sites on a weekly basis, and in all other flowing boreholes at least monthly. Temperature and conductance are generally done in the field with portable equipment.

* Seasonal monitoring of selected sites should provide valuable insight into the source and proportion of recharging water from the various sources indicated.

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Follow-up sampling of all the major underground and surface water sampling sites should be performed as follows:

* One month after the tailings pond diversion
* During the 1991 fall recharge event (end of November)
* Mid-winter
* After the spring recharge event (April)

* At a minimum, each seasonal sampling set would include in-situ measurement of dissolved oxygen temperature, pH, Eh, conductance; major ion chemistry analysis and selected isotope analysis. The number of stations would be reduced to 15 underground sites, and 5 surface water sites. The results should be collated, and reviewed by a hydrogeochemist.

* Monthly samples should be collected at the Class 1 sampling sites for analysis of major ion chemistry (e.g. RCA). Samples of Gays River Water at stations B1, B3, and B14 should be collected at the same time.

* New mine water inflows should be sampled and analyzed for major ion chemistry, and temperature, soon after they are discovered, and compared with the baseline data. This may indicate possible water sources.

* Environmental isotopes, although expensive and require a long analysis turnaround, are useful indicators of mine water source and age. One or more of the major drain holes could be selected for quarterly isotope analysis for tritium, deuterium and oxygen-18.

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5.1.3 Comments on Weekly compliance monitoring parameters, frequency, protocol

* A comparison of field pH with lab pH indicates a very good correlation, suggesting little change in pH between point of sampling and lab analysis. Therefore, field pH determinations need not be done, lab pH should be adequate.

* The turbidity measurements from the lab analysis are cheaper than suspended solids determinations. Alternately, Westminer could utilize a turbidity meter for their own analysis. A correlation of turbidity and suspended solids could be made using monthly of weekly compliance data sets. A reasonable correlation between turbidity and suspended solids was obtained from this data set.

* The weekly major ion chemistry and metals analysis at the mine water discharge point could be reduced to monthly. This should be augmented with daily monitoring of temperature and suspended solids, and weekly monitoring of MMLEG metals, pH, alkalinity and sulfate similar to the other compliance stations.

* The review of metals data for the mine discharge water (108 samples) indicates that only a few parameters are useful for mine water monitoring (Table 2). The remaining parameters either are consistently below detection, or show negligible variation over two years of monitoring. Key metals include: iron, manganese, lead, zinc, arsenic, boron, and strontium. Elimination of mercury and a reduced metals scan to 6 parameters should result in a cost savings of up to $45 per sample.

* A review of the compliance monitoring data indicates no mercury (detection limit 0.05 ug/L) has been detected at the tailings pond outfall (WCI-GR1) in

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2 years. This element could be eliminated from the weekly scans, and run on a monthly basis. With the exception of the past two months, mercury was largely absent from Compliance Station A as well.

* Any change to the existing monitoring program must receive approval from NSDOE. The two years of data are sufficient for a revision of the monitoring program.

5.2 Sink Hole Investigations

Recent investigations have identified a significant loss of stream water along the Gays River between Sinkhole # 6 and Sinkhole #5. This was confirmed to some extent by the profiling program conducted as part of this investigation (Locations 4, 8, 11, and possibly 5 and 12). Some additional hydrological-hydrogeological investigation is warranted to confirm the active sinkholes.

5.2.1 Hydrogeological Investigations

A series of mini-piezometers and seepage meters should be installed adjacent to and on the bottom of the suspected active sinkholes. (The new shallow monitor wells currently being installed may be sufficient to determine vertical gradients). The mini-piezometers, consisting of small diameter pipe or tubing with a screened tip, would be installed (hand augur or driven) from a boat or temporary platform approximately 1 to 2 metres into the floor of a sinkhole. Water level would then be measured relative to river surface. A level lower than the river would indicate an influent condition, and an active sinkhole. A level higher than the river water would indicate an effluent condition, or recharge from the underlying aquifer. It is expected that the degree of vertical gradient between river and underlying aquifer would vary seasonally.

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Where a downward vertical hydraulic gradient is confirmed, quantification of the flow rate should be determined from seepage meter tests. This would involve installation of a seepage meter (top of a 45 gallon drum of known cross-sectional area) into the stream sediments, attach a polyethylene bag containing a known volume of water, measure the remaining volume after a specified time, and calculate the seepage flux in litres per minute per cross-sectional area. Several tests would be performed at each site to obtain statistically good results, and to determine variation in recharge at different seasons.

Temperature/conductivity profiles of the river bottom at different times of the year may be useful in delineating zones of discharge from groundwater into the river, and zones where the river may be recharging the river bottom.

5.2.2 Tracer Testing Methods

Where an influent sinkhole is identified by the above works, tracer testing may be conducted to identify pathways into the mine workings. The tracer should be injected directly into the bottom of the sinkhole by pumping through a piezometer or screened borehole installed for this purpose. This will reduce the tendency for dilution and dispersive losses to the river passing by the sinkhole.

Since the concentration of chloride is low in the river and in the mine water, salt could be introduced at a level which would be innocuous to aquatic organisms (say, 1000 mg/L). The electrical conductivity of the mine discharge water could be continuously monitored in the mine waters and samples taken at closely spaced intervals from sites in proximity to the injection point. The difference between the concentration of the river water and that of the mine water discharge will allow determination of the amount of river water entering the mine.

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Monitoring should also be conducted at all flowing monitor bores underground and in any nearby shallow sand monitoring wells for a period of at least one month. Rapid transmission would indicate direct continuity, possibly through a solution channel. An indirect pathway, such as through the shallow sand aquifer, may result in considerable dilution, and several days transit time.

Fluorescent dyes are recommended since they are less likely to be attenuated by dilution and ion exchange in surficial deposits than chloride tracers, and can be readily detected at low concentrations underground using portable fluorescence meters. Injection of a salt brine may also be possible since background chloride concentration is low (about 12 mg/L), however it should also be injected directly into the subsurface.

5.3 Recommendations for Further Work

The vast amount of hydrochemical data generated over the past two years and new data currently being could be analyzed in greater detail than possible within the scope of this assessment to determine the proportion of water entering the mine from various sources. This information should be reviewed and assessed by a hydrogeochemist using computer techniques to determine the degree of saturation and mixing of various ions. This work can be performed on the existing database, and should also be performed on the spatial data, after a few more data sets have been generated.

Several hydrochemical techniques could be employed to determine the proportion of surface water in the mine.

Mass balances calculations using trace metals such as arsenic could be used to calculate the percentage of river water in the mine effluent, based on differences in As concentration, weir discharge rates and river flows. Also, Mg^{2+} is known to vary linearly with HCO_3^- in the mine

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waters (after July 1, 1990) and this could be used to determine the percentage of mine waters at a given time which are likely to have originated in the carbonates.

A better assessment of deep well water and chemical stratification should be made through pumping tests with chemical monitoring of D.O., pH, Eh, conductance, alkalinity, and sulfate.

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6.0 REFERENCES/BIBLIOGRAPHY

Craig, H. (1961). Isotopic Variations IN Meteoric Water. Science 133: 1702.

Dames & Moore Limited (1974) for Kilborne Engineering Limited, Imperial Oil Limited, Cuvier Mines Limited. Reconnaissance Hydrogeology IOL/Cuvier Mines Proposed Lead-Zinc Mine, Gays River, N.S.

Dames & Moore (1980). 1979-80 Groundwater Program; Gays River Diversion and Flow Regulation Feasibility Investigations, Gays River Mine, N.S. Report to ESSO Minerals Canada and Canada Wide Mines.

Dansgaard, W. (1964). Stable Isotopes in Precipitation. Tellus 16: 436.

Fritz, P., Drimmie, R.J., Frape,S.K., and O'Shea, K. (1987a). The Isotopic Composition of Precipitation and Groundwater in Canada. In: Proceedings IAEA-SM-299/17. pp. 539-550.

Hannon, P. (1981). Report on Trench Geology. Canada Wide Mines Internal Report.

Health & Welfare Canada (1989). Guidelines For Canadian Drinking Water Quality.

Jacques Whitford & Associates Limited (1981). Geotechnical Investigation of Gays River Mine, Gays River, N.S. JWA Project No. 2192, Aug. 1981. For Canada Wide Mines.

Jacques Whitford & Associates Limited (1985). Gays River Sand Exploration, N.S. JWA Project No. M1276, for Seabright Resources Inc.

Jacques Whitford & Associates Limited (1990a). Gays River Overburden Stability Investigation, Phase 1. JWA Project No. 5937. Report to Westminer Canada Limited.

Jacques Whitford & Associates Limited (in prep). Gays River Overburden Stability Investigation, Phase 2. JWA Project No. 5937. Report to Westminer Canada Limited.

Leggette, Brashears & Graham INC. (1982). Phase I Hydrogeological Investigation of Gays River Mine. April 1982. For ESSO Minerals Canada and Canada Wide Mines Limited.

Martec Limited (1981) Gays River Bathymetric Survey. Dec. 1981. Report to Canada Wide Mines Limited.

Martec Limited (1988) Gays River Bathymetric Survey. Dec. 1988. Report to Westminer Canada Limited.

Martec Limited (1989a) Gays River Bathymetric Survey. May 1989. Report to Westminer Canada Limited.

Recycled Paper

Martec Limited (1989c) Gays River Continuity Survey. November 1989. Report to Westminer Canada Limited.

Martec Limited (1990a) Gays River Bathymetric Survey. June 1990. Report to Westminer Canada Limited.

Martec Limited (1990b) Gays River Bathymetric Survey. September 1990. Report to Westminer Canada Limited.

Martec Limited. (1991a). Hydraulic Connection Between Taylors Pond and Underground Seepage. Report to Westminer Canada Limited, Jan. 1991

Martec Limited (1991b). Gays River Seepage Study. Report to Westminer Canada Limited. July 1991.

McKee, D.M. and Hannon, P. (1982). The Hydrogeologic Environment of Gays River Mine. ESSO Mineral Resources Limited Internal Report. 26p.

Meyer, G.M. (1991). Gays River Mine De-Watering and Water Inflow Prevention Study. Internal Report. Western Mining Corp. Limited, Exploration Div. (Australasia). February, 1991.

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